Physical Science

INTERACTION OF MATTER AND ENERGY

EACHER'S GUIDE

EATH / MACNAUGHTON

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PHYSICAL SCIENCE:
INTERACTIONS OF MATTER AND ENERGY

Macnaughton/Heath

TEACHER'S GUIDE

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FOREWORD

For many years teachers of science have been aware of the advantage of a student-oriented inquiry approach to learning and have begun to develop curriculum materials to that end. The authors share that commitment and feel that **Physical Science** offers a challenging and stimulating approach based on student investigations. The investigations have been chosen for their interest and reliability and have been woven carefully into a conceptual framework which both teacher and student must be aware of. It is this conceptual scheme which renders **Physical Science** different from many textbooks currently being used.

The theme of the book is the development of the kinetic-molecular theory, which has been divided into three parts: first, that all matter is composed of elementary particles called atoms; second, that these particles are in constant motion and move faster at higher temperatures; and third, that these particles interact by means of the electric force, in physical and chemical reactions.

The authors feel the scientific method should be intimately involved in all classroom work. We see this method of scientific problem solving as being characterized by the following stages:

1. **Identifying** the Problem: The learner must be able to identify and state clearly the problem he is attempting to solve.

2. **Observing** Fundamental Characteristics: The learner must be able to observe some of the fundamental parameters of the problem and familiarize himself with some of the variables affecting the solution to his problem.

3. **Hypothesizing:** The learner must be able to use these observations to form hypotheses about the solution to his problem.

4. **Testing** the Hypotheses: The learner must be able to design and perform experiments to test the validity of his hypotheses, and from these tests determine which, if any, of his hypotheses is most suitable as a solution to his problem.

5. **Predicting**: The learner must be able to use his best hypothesis to explain other known phenomena and to predict the outcome for other unknown phenomena associated with his problem.

Physical Science employs this scientific method of problem solving in its conceptual framework, as below:

Basic Problem: What is the nature of the structure of matter?

Chapter	Stage in Scientific Method	Chapter Content
0.0		Basic measuring, tabulating and graphing techniques. The scientific method of problem solving.
	CYCLE 1	
1.0 Dissolving	Observing	Observation of the process of dissolving and a study of the properties of solutions.
2.0 Theories of Matter	Hypothesizing	Forming hypotheses concerning the structure of matter: continuous theory vs. particle theory. Fundamental evidence for the particle theory.
3.0 Crystals	Testing	A study of the properties of crystals, techniques for making crystals, and the role of crystals in providing evidence for the particle theory.
4.0 Density	Predicting	A particle theory treatment of the densities of solids liquids and gases. Calculations of density and relationship between density and bouyancy.
	CYCLE 2	
5.0 Heat and Temperature	Observing	Observation of the effects of heat on solids and liquids. Measuring quantities of heat and introduction to specific heat capacity. The joule as a unit of heat.
6.0 Changes of State	Observing	Properties of the three states of matter and changes of state. Boiling and freezing of solutions and the effect of pressure on boiling.

7.0 Particles in Motion	Hypothesizing and Testing	Forming hypotheses concerning the nature of heat: caloric fluid theory vs. particle motion theory.
	CYCLE 3	
8.0 Work	Observing	Definition of force, work, and examples of heat, light, and electricity doing work. Introduction to simple machines.
9.0 Energy	Observing	Definition of energy in terms of work. Kinetic, gravitational potential, and chemical potential energy. The energy crisis: the problem and some possible solutions.
10.0 The Force Between Particles	Observing Hypothesizing and Testing	Introduction to the concept of forces holding particles together. Forming hypotheses concerning the nature of these forces. Evidence for the electrical nature of the force.
11.0 Reactions Between Particles	Predicting	Introduction to chemical reactions. Application of the kinetic molecular theory to rates of reaction. Introduction to the periodic table.

The text consists of 79 investigations organized into twelve chapters. These investigations may be replaced or supplemented by 52 further investigations, some of which are located at the end of each chapter. At the end of each chapter as well is a list of instructional objectives that tell the students what they must be able to do as a result of their learning (all tests and examinations should be based on these lists), a summary (a list of new concepts), a review (a set of homework problems), and a glossary (a list of words whose definitions may be found in the main glossary at the back of the text).

The graphics and illustrations used in **Physical Science** represent a marked departure from traditional science textbook format. Captions and labels have been omitted deliberately from the illustrations since the authors feel that students usually overlook captions and do not need labels when identifying most laboratory equipment. The full-page graphics are intended to stimulate discussion as well as contribute colour to the text. They relate directly to the material in each chapter. Students should be encouraged to examine them carefully and to talk about what they reveal.

The text has been approved by the Metric Commission in Ottawa, and so carries the metric symbol which signifies that proper metric units and symbols are in use throughout. Teachers will find new challenges measuring heat in joules and forces in newtons.

No investigation is worth doing if injury to a student results. Always emphasize the following:

- Never taste any substance found in the science laboratory.
- Never smell any substance unless instructed to by the teacher.
- Be careful with loose clothing and long hair near Bunsen burners.
- Do not point test tubes containing boiling liquids at anyone. The liquid can easily fly out and hit someone in the face.
- Stay at your own desk during investigations as much as possible. People moving up and down aisles cause accidents.

In addition, we have noted certain hazardous situations that might arise in some investigations. In each case, a warning symbol (hand) has been placed in the margin, together with the following words denoting the nature of the potential danger:

Noxious gas – a gas or vapour is either used or produced, which is noxious and may present a respiratory danger if inhaled in quantity.

Electric shock – a source of electrical power is used which, if improperly connected or if in a poor state of repair, may cause an electrical shock.

Fire – a flammable substance is either used or produced and, if used near an open flame or where a spark may occur, could ignite and cause a fire.

Broken Glass – a delicate piece of glassware is used or a potentially dangerous procedure involving glassware is carried out, either of which may cause lacerations due to glass breakage.

Corrosive material – a corrosive substance (usually a strong acid or base) is either used or produced, which may result in burns to the skin or clothing.

Explosion – an explosion may occur due to combustion or to a significant increase in pressure. This also includes the possibility of an implosion, where a vacuum exists.

In including these warnings, the authors are assuming the position of being overly precautionary.

EQUIPMENT AND SUPPLIES

Equipment and supplies needed for the course have been presented in two ways in the teacher's guide. First, a list of materials, to be used in organizing each day's work, is included along with the discussion of each investigation. Quantities given are for a class of thirty students working in pairs. Second, the materials needed for each investigation have been combined in one master list at the front of the text, and have been classified as basic laboratory equipment, chemicals, or physics equipment. The quantities given for non-consumable equipment are for one class of thirty students working in pairs (fifteen sets). The quantities for consumable supplies and chemicals are for five class sets of thirty students working in pairs. The master lists are for your convenience in ordering supplies at the end of each year.

BASIC LABORATORY EQUIPMENT

1 class set of 30 students – 2 per group

15	retort stands
15	ring clamps
15	wire gauze, asbestos
15	Bunsen burners
15	flint lighters
15	test tube racks
30	100 ml grad. cylinders
15	10 ml grad. cylinders
30	250 ml beakers, grad.
30	500 ml beakers, grad.
150	20 x 150 mm test tubes
30	13 x 100 mm test tubes
15	25 x 200 mm test tubes
15	glass stirring rods
15	plastic funnels
45	thermometers, -10° to 110°C
15	mortar and pestles
5	dropper bottles
30	watch glasses
15	250 ml boiling flasks
15	1 hole stoppers for flasks
20	eyedroppers
15	stereo microscopes
15	microscopes
15	microscope slides
15	cover slips
15	crucibles
15	Petri dishes
15	electrolysis app.
15	rectangular sponges
1	double pan balance
15	triple beam balances
15	glass tubes, 2 cm x 50 cm
15	# 4 rubber stoppers
15	# 8 rubber stoppers
15	large corks
15	# 4 1 hole stoppers
15	test tube holders

CHEMICALS

5 class sets of 30 students – 2 per group

400		sugar cubes
400	g	sodium chloride (NaCl)
800	g	potassium nitrate (KNO_3)
2	kg	copper sulphate, fine crystals $CuSO_4 \cdot H_2O$
400	g	sugar, granulated
400	g	ammonium chloride (NH_4Cl)
3	kg	sodium thiosulphate ($Na_2S_2O_3 \cdot 5H_2O$)
50	ml	liquid laundry starch
5	kg	sand
5	kg	rock salt (NaCl)
4	ℓ	methyl hydrate, methanol or methyl alcohol (ditto fluid)
100		flints for lighters
15	g	potassium permanganate ($KMnO_4$)
25	g	salol, salicylic acid phenyl ester, phenyl salicylate
200	ml	carbon disulphide (CS_2)
50	g	flowers of sulphur
4	kg	alum ($KA1(SO_4)_2 \cdot 12H_2O$)
4	kg	chrome alum, chromic potassium alum ($CrK(SO_4)_2 \cdot 12H_2O$)
600	sh	filter paper
10	g	silver nitrate ($AgNO_3$)
500	g	Rochelle salt, potassium sodium tartrate ($KNaC_4H_4O_6 \cdot 4H_2O$)
500	g	nickel sulphate ($NiSO_4 \cdot 7H_2O$)
2	ℓ	oil, 10W30
12	ℓ	anti-freeze, ethylene glycol, glycol, 1,2 – ethanediol
2	ℓ	conc hydrochloric acid ($HC1$)
15	ml	aluminum foil
4	kg	roll sulphur
100	g	1,1,2,2 tetrabromoethane, density 2.96g/ml
100	g	butyl carbitol, diethylene glycol, monobutyl ether
75	doz	Alka-Seltzer tablets
25	g	iodine crystals
300	ml	homo milk
1	pkg	wooden splints
2	kg	copper shot
5	lb	zinc dust
2	ℓ	soap solution
15	m	wax paper
5	m	magnesium ribbon
100	g	potassium iodide (KI)
100	g	lead nitrate ($Pb(NO_3)_2$)
250	g	ammonium dichromate ($(NH_4)_2CR_2O_7$)
100	g	sodium hydroxide (NaOH)
4		large crystals each of sugar, salt, copper sulphate ($CuSO_4 \cdot 5H_2O$) and potassium nitrate (KNO_3)
15		large salt crystals (halite)
5		large calcite crystals
75		large baby food jars
1		crystal collection, misc.
1000	sh	mm graph paper
150		250 ml styrofoam cups
1		ball string
1		spool thread
10		sheets sandpaper

PHYSICS EQUIPMENT

1 class set for 30 students – 2 per group

30	metre sticks
15	cloth metric tapes, 1 m
15	cardboard litre cubes
15	plastic ml cubes
15	empty quart milk cartons
15	small stones
15	wooden blocks
15	lead cubes
1	metric bathroom scale (kg)
15	magnifying glasses
2	hot plates
100	single-edged razor blades
30	3/4" wooden dowels, 5 – 15 cm long, varnished
15	sets density objects: wooden blocks, marbles, stoppers, cubes, rocks, ping pong balls, dice, etc.
15	weighted wooden sticks, simple hydrometers
15	pr scissors
50	5/8" washers
1	plastic dish pan
15	immersion heaters, single or double
30	elastic bands, 10 cm
15	rulers, 30 cm
1	box toothpicks
1	bottle ink
1	roll Whatman's No 1 chromatography paper, 20 mm x 100 m long
2	rolls masking tape (15 m each)
3	Brownian motion smoke cells
1	electric fan
15	spring balances (newtons)
45	wooden blocks, with hooks and eyes
15	dynamics carts
15	ramps, 25 cm x 1 m
15	lever apparatus
15	single pulleys
15	double pulleys
15	sewing needles
15	drinking straws
15	protractors
15	bimetallic strips
15	wooden sanding blocks
30	m copper wire
15	1-1/2 volt batteries
30	bar magnets
15	radiometers
15	light bulb sockets
5	each 25W, 40W, 60W, 100W, light bulbs
30	drapery track, 50 cm long
15	wooden energy blocks
15	regular marbles
15	large marbles
15	3/4" ball bearings
15	special wire loops
15	large rubber bands
15	sets of masses
15	mass hangers
15	electrostatics kits: vinyl strips, acetate strips, wool, cotton, glass and ebonite rods, etc.
2	kg iron filings
15	6 volt power supplies for electrolysis

Please note that the dowling, masking tape, washer and ball bearing manufacturers have not yet gone metric.

Possible Course Timing Sequence

	Instructional Days
Introduction	4
Chapter One: Dissolving	12
Chapter Two: Theories of Matter	13
Chapter Three: Crystals	16
Chapter Four: Density	16
Chapter Five: Heat and Temperature	16
Chapter Six: Changes of State	18
Chapter Seven: Particles in Motion	13
Chapter Eight: Work	16
Chapter Nine: Energy	12
Chapter Ten: The Force Between Particles	16
Chapter Eleven: Reactions Between Particles	13
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Based on a school year of one hundred eighty five instructional days of forty minutes instructional time per day, and allowing twenty days for exams, assemblies, etc.

INTRODUCTION

This introduction, basically a primer in doing experiments, (or, as we call them, investigations) includes the steps in the scientific method, how to write a lab report, a sample lab report, metric units of length with their prefixes, and short sections on making up data tables and drawing graphs.

Many students will need all of these sections, some may have never drawn a graph or measured in centimetres. Judge which sections to use and which to skip.

0.1 The Scientific Method

A case history illustrates the steps in the scientific method, as well as its usefulness.

0.2 Writing a Laboratory Report

The reasons for making lab reports, a system for writing reports, and a sample lab report are included.

0.3 The Metric System

An introduction to metric units of length, proper symbols, metric prefixes and sample distances. An exercise with measuring tapes encourages estimation and accurate measurement of distances.

0.4 Setting Up Data Tables

A special section to examine the problem of reading an investigation and then setting up a data table to record the observations. Sample data tables are included.

0.5 Drawing a Graph

A step-by-step introduction to the drawing of graphs, starting with a data table, this includes the drawing and labelling of axes, the plotting of points, the drawing of smooth curves, the use of a ruler if necessary for straight lines.

0.6 Review

A set of problems involving the drawing of graphs, looking for relationships on graphs, and reading of graphs. For the more advanced, using equations to draw graphs and obtaining the equation of a graph.

0.7 Instructional Objectives

An introduction to instructional objectives and their importance in determining what is to be learned and how to know when it has been learned.

CHAPTER ONE – DISSOLVING

Chapter Objectives and Philosophy

The first interaction, the process of dissolving, is examined in chapter one. A sugar cube is observed as it dissolves, looking for evidence that it is still present in the solution. This turns out to be unexpectedly difficult, especially after the solution is stirred a few times with a glass rod. Measurement as dissolving occurs shows that the mass is unchanged, which suggests that the sugar is still there. The law of conservation of mass is used without being stated. Other solutions are examined to find similarities in behaviour, so that solutions may be identified. Then the properties of saturated and unsaturated solutions are examined – the first interactions involving heat.

Metric units are defined as they are needed, and practice exercises are included for all but the more advanced students. The difference between mass and weight is discussed briefly, and then the terms weight and weighed are used only when they refer to the force of gravitational attraction to the earth.

1.3 Measuring – Volume

This investigation gives practice in measuring and calculating the volume of various regular and irregular objects. The metric units of litre, ml, m^3 and cm^3 are introduced. Students should be encouraged to work carefully and to consider possible sources of experimental error.

Materials

15 100 ml graduated cylinders
15 empty milk cartons (1 quart size)
15 rectangular plastic sponges
15 rubber stoppers (to fit easily in graduated cylinder)
15 250 ml beakers

There are five measuring exercises in this investigation. The teacher must decide how much direction to give the students – either listing the procedures in pre-lab discussion or letting the students work the steps out on their own.

1. Fill the milk carton with water, then measure the volume of the water with the graduated cylinder.
2. Measure the length, width and height of the milk carton, then calculate its volume in cm^3.
3. Change the volume in cm^3 to m^3 and ml. Compare with measured result.
4. Measure the volume of the rubber stopper by the displacement of water in the graduated cylinder.
5. Calculate the volume of the sponge in cm^3, by measuring its length, width and height.
6. Measure four different volumes of water into a beaker, and then measure the total volume of the water. Compare with calculated total of volumes (100 ml). Discuss experimental error.

The first decision students have to make is how full to fill the milk carton. If they ask, tell them to fill the rectangular part of it. The volume should be about one quart, which is exactly 1136.522 ml.

Calculate the volume of the rectangular part of the carton. If possible errors are discussed, students might suggest:

(a) they are measuring the outside, but they want to know the volume of the inside of the carton.

(b) when filled with water, the sides of the carton bulge out a little, changing the volume inside.

Finding the volume of the rubber stopper is a good problem for students to work out on their own. Many solve it quickly, but the rest struggle on, trying to figure out why the volume is measured before the stopper is put in, etc.

The volume of the sponge makes them think. Should the holes be included? Soak the sponge in water, then squeeze it out in the graduated cylinder. This volume is roughly the volume of the holes. The "actual" volume of the sponge can be found by subtraction. Later on, after atoms have been introduced, some students may question the whole idea of volume. After all, if you don't count the holes in the sponge, should you count the space between atoms, the space inside atoms, the space inside protons and neutrons, etc.?

The four volumes of water add up to 100 ml. In actual practice, the students might be as much as 10 ml out, depending on how careful they are. They might like to discuss the various problems involved, such as:

(a) the difficulty in reading the meniscus (something they should be shown before they start).

(b) the water left in the bottom after the rest is poured into the beaker, and the water left in the beaker after it has been poured back into the cylinder.

Although volume is a very important concept, as is the importance of accurate measurement, this investigation should not take any more than 2 periods, with perhaps another half period of discussion. Measuring too many volumes may become boring.

REPORT ON INVESTIGATION 1.3

NAME____________________ CLASS_______ DATE_______

PROBLEM: How do you measure and calculate volume?

MATERIALS:
100 ml graduated cylinder
250 ml beaker
empty milk carton
rubber stopper
plastic sponge

OBSERVATIONS:

1. Volume of milk carton: Fill it with water, then measure the volume of the water with the graduated cylinder.

volume =_______ ml

2. Volume of milk carton: Measure it with a 30 cm ruler.

length =________ cm
width =________ cm
height =________ cm

volume =__________ cm^3
=__________ ml
=__________ m^3

3. Volume of rubber stopper: Drop it in a half-filled graduated cylinder.

volume of water before adding stopper =__________ ml
volume of water after adding stopper =__________ ml
volume of stopper =__________ ml

4. Volume of sponge:

length=________ cm
width=________ cm
height =__________ cm
volume=__________ cm^3

Describe how to find the volume of the holes in the sponge and then do it.

5. Accuracy in measuring volume:

Total volume of water in beaker, as measured in cylinder =________ ml
Total volume of water in beaker, as calculated =_____ ml

Experimental error =_______ ml

Average error per measurement =_____ ml

1.5 Dissolving Sugar Crystals

Students in this investigation watch a sugar cube dissolve and look for evidence that the sugar is still there in a different form. After stirring, they end up with a clear colourless liquid. They all know the sugar is there, because they know what would happen if they tasted it, but they will have trouble proving it. Especially since they are told at the beginning of the investigation that they are never allowed to taste anything in science class. The beaker, the stirring rod, or the sugar cube might be contaminated. Use this moment to encourage them to clean up carefully after every investigation to avoid accidents.

The only good visible evidence of the sugar in the water are some streams of denser water leaving the cube. Only the most observant will notice these the first time around.

Materials

15	250 ml beakers
15	glass stirring rods
15	sugar cubes

1.6 Can You Trust Your Senses?

Students compare distances of some optical illusions. Only by accurate measurement can they reach the proper conclusion.

1. The hat looks taller than its width, but it is 3.2 cm tall and 3.5 cm wide.
2. AB looks longer than CD, but AB is 2.6 cm long and CD is 2.8 cm long.
3. GH seems longer than EF, but GH is 3.0 cm long and EF is 3.2 cm long.
4. A seems to be smaller than a, but they are both the same size.

Do these together in class, first without measuring, and then again, measuring each one carefully. Many students have seen optical illusions before and remember that the objects in question are usually the same length. It never occurs to them that they might be the opposite of what they appear. Take a vote on each one the first time through and record the results on the board. The results are hilarious.

Materials

15	30 cm rulers marked in millimetres

1.8 Weight – Mass

Weight and mass are compared. Try to convince the students that mass, measured in kg and g, is the term to use. The terms “weight” and “weighing” are carefully avoided in the text.

Materials

15 100 ml graduated cylinders
15 balances of your choice
15 wooden blocks
15 lead masses
15 large corks
15 large rubber stoppers

In the pre-lab, give a standard lesson on balances – handling, making proper measurements, etc. Finding the masses of solid objects is straightforward, but finding the mass of water can be tricky. Do not discuss this beforehand, let students do it themselves. Most forget to subtract the mass of the empty cylinder. Ask them to report the mass of 1 ml of water to you as soon as they have calculated it so that you can get them on the right track as soon as possible.

1.9 Mass – Volume

The total mass of a beaker of water and some sugar cubes is measured before and after dissolving. The idea is to provide evidence from accurate measurement that during dissolving the solute does not disappear. Though not stated, this investigation is also evidence for conservation of mass itself. The student may report a small change in mass. Ask him how this change compares to the mass of a sugar cube (it should be quite small) and whether he believes that the mass really did change. This can lead to a discussion of possible experimental errors.

Materials

15 250 ml beakers
15 glass stirring rods
15 balances
45 sugar cubes

1.10 Other Solutions

In this investigation, other solutions are compared with sugar solutions in an effort to find the common characteristics of solutions. As well, they are introduced to the basic lab skills of folding filter papers, filtering, evaporating a drop of solution. Many find it difficult to follow a series of tests such as this efficiently. Encourage them to work systematically.

Materials

120 20 x 150 mm test tubes (capacity 34 ml)
15 funnels
60 filter papers
15 microscope slides

15 stirring rods
15 magnifying glasses or stereo microscopes
2 hot plates
30 g sodium chloride (works better than table salt)
30 g potassium nitrate
30 g copper sulphate (fine crystals)
30 g sugar

Solubility (g/100 ml of water at 0°C)

sodium chloride	35.7
potassium nitrate	13.3
copper sulphate	31.6
sucrose	179.0

Encourage them to use their balances to measure out 2 g of each substance so that all the solute will dissolve easily, as it should.

1.12 Heat – Temperature

This is another introductory section, this time to temperature measurement and the degree Celsius. As with the other sections like this (length, volume, mass) you must decide whether it is necessary to do this work. Students must both measure and estimate temperatures. At no time should Fahrenheit degrees be measured, or "easy" ways to convert from one scale to another be introduced.

Materials
15 Celsius thermometers (-10°C to 110°C)
15 250 ml beakers

Thermometers that have both Fahrenheit and Celsius scales should be thrown away.

1.13 Temperature – Solutions

They try to dissolve potassium nitrate in cold water, but some remains. Heating enables the rest to dissolve. When cooled, the crystals reappear at about the same temperature at which they dissolved. It looks like a solution can only hold a certain amount of solute at a given temperature. It can be saturated.

Materials
15 13 x 100 mm test tubes (capacity 9 ml)
30 250 ml beakers
15 test tube holders
15 retort stands
45 g potassium nitrate
15 ring clamps
15 Bunsen burners
15 thermometers
15 wire gauze

The solubility of potassium nitrate is as follows:

at 0°C 13.3 g/100 ml water = 0.67 g/5 ml of water
at 20°C 31.6 = 1.6
at 100°C 247 = 12.3

All the solute should dissolve at about 30°C, if they have measured out the amounts carefully.

CHAPTER TWO – THEORIES OF MATTER

Chapter Objectives and Philosophy

In chapter one, many questions are asked but few are answered. In chapter two, the continuous and particle theories of the ancient Greeks are suggested as possible hypotheses to the above questions. A simple experiment suggests that solutions, dispersions and suspensions are different only because of particle size. Finally, the change in volume of solutions as they are made suggests that there are spaces inside matter, perhaps spaces between particles.

2.6 Solutions and Other Mixtures

Students examine solutions, dispersions and suspensions to compare their properties and, secondly, to explain their properties in terms of a simple particle model.

Materials
90 20 x 150 mm test tubes
15 test tube racks
15 funnels
45 filter paper
1 light source such as an overhead projector, filmstrip projector
45 g copper sulphate, fine crystals
5 ml liquid laundry starch
45 g soil

One drop of liquid laundry starch in a test tube of water is sufficient to make an ideal dispersion.

Decide how far to go in this exercise. Either shine light beams through the mixtures to see which one transmits the best and then stop, or go on to examine the scattered light and discuss the Tyndall effect.

2.8 Volume of Mixtures

Students measure the volume of a mixture to see if volume is conserved. This investigation is intended as an introduction to 2.9 and 2.11.

Materials
30 100 ml graduated cylinders
750 ml sand

Students should have no difficulty in seeing that the volume decreases because the water fills in the spaces between the grains of sand.

2.9 Volume of Solutions

In this investigation students measure the volume of a rock salt solution before and after dissolving. The volume decreases a few millilitres.

Materials
15 100 ml graduated cylinders
750 ml rock salt

They will have other explanations for their observations at first, such as evaporation, spillage, etc. Encourage them to check these theories by doing simple experiments, such as shaking 100 ml of water to see how much is lost, letting 100 ml of water sit for a few minutes to see how much evaporates, and so on.

On the other hand, they may get bogged down with these little investigations and lose the thread of the argument. It is probably enough at this point that they see the particle model as a possible explanation for the observations.

2.11 Composition of Liquids

The student measures the volume of a solution of alcohol and water as it dissolves. Once again, the volume decreases slightly and the particle model explains the phenomenon.

Materials
30 100 ml graduated cylinders
15 250 ml beakers
15 stirring rods
750 ml alcohol (ditto fluid is perfect)

The procedure in the text is slightly more sophisticated than is normal. The alcohol, coloured perhaps with a little potassium permanganate, is poured gently down the side of the graduated cylinder, where it floats on top of the water. With care, very little mixing takes place and the volume can be read easily. Then, with one fast stir, the volume magically decreases. For slower groups, a simpler procedure is suggested. Pour exactly 50 ml of water into one graduated cylinder and exactly 50 ml of alcohol into another. Pour the water into the alcohol (to mix it without stirring).

CHAPTER THREE – CRYSTALS

Chapter Objectives and Philosophy

By the end of chapter two, students should be fairly sure that the particle theory is correct. The experiments with crystals in chapter three are designed to convince them. Students examine crystals, watch crystals form, cleave crystals, and grow large crystals in various kinds of interactions. All the observed behaviour can be explained if crystals are formed by tiny identical particles attaching themselves together in straight rows and columns.

3.3 Looking at Crystals

Students in this investigation examine various crystalline materials, noting their shapes, sizes, colours. In particular, impress them with the flat sides, sharp corners, equal angles, similar shapes.

Materials

10 stereo microscopes, magnifiers, as needed
10 crystal samples
Possible Crystals

salt (halite)	$NaCl$
sugar	
potassium nitrate	KNO_3
copper sulphate	$CuSO_4 \cdot 5H_2O$
ammonium chloride	NH_4Cl
sodium sulphate	Na_2SO_4
sodium thiosulphate	$Na_2S_2O_3 \cdot 5H_2O$
potassium permanganate	$KMnO_4$
nickel sulphate	$NiSO_4 \cdot 7H_2O$
alum	$KAl(SO_4)_2 \cdot 12H_2O$
chrome alum	$CrK(SO_4)_2 \cdot 12H_2O$
Rochelle salt, potassium sodium tartrate	$KNaC_4H_4O_6 \cdot 4H_2O$

Teachers may have to grow samples of some of these to get perfect crystals. Large crystals of some materials are available from supply houses. Set these up at various points around the room and organize a rotation from station to station.

EXERCISE: LOOKING AT CRYSTALS

SAMPLE

same size?					
same shape?					
sketch shape					
colour?					
transmits light?					
edges? angles? sides?					
others the same?					

3.5 Supersaturated Solutions and Crystal Formation

The students make a supersaturated solution with sodium thiosulphate, seed it with another crystal, and watch the extra hypo crystallize out.

Materials
15 20 x 150 mm test tubes
15 test tube holders
15 250 ml beakers
15 Bunsen burners and spark lighters
750 ml sodium thiosulphate

Two drops of water are more than enough to dissolve 40 or 50 hypo crystals without heating. One of the students might like to try the procedure, adding the crystals one by one as they dissolve.

In 1.13, students found that a solution can dissolve more solute as it is heated but releases excess solute as it is cooled. Here they should be surprised to find that sometimes the excess solute can remain in the solution. In 1.14, they found that many substances cool a solution as they dissolve. As solutes crystallize, therefore, they might release that heat energy.

Be sure to go around and tell students to feel the test tube as the crystals form, since many do the investigation without noticing that a considerable amount of heat is given off.

3.6 Crystal Formation from Molten Materials

This investigation involves heating a small sample of salol on a microscope slide and watching the crystals grow as the salol cools. Sometimes a seed crystal is needed.

Materials

15 microscope slides
15 magnifiers, microscopes, stereo microscopes or one projection microscope
5 g salol
1 hot plate

This procedure works well either as a class investigation or on the projection microscope. Do the exercise over and over as the students watch with amazement. Naturally, emphasize that the crystals always grow in the same way, with the same shape.

3.7 Using a Theory to Make Predictions

Students make crystal shapes by combining "particles" (here they are circles), in regular rows. After they have worked at it for a while, summarize their findings on the overhead projector using a bunch of pennies. A nickel or a quarter can show the effect an odd-sized particle has on the shape of the crystal. The same investigation may be done in three dimension using marbles glued together with drops of wax from a candle, or using styrofoam balls stuck together with toothpicks.

Materials

15	dimes (supplied by student)
	or
300	marbles
15	wax candles (stick the marbles together with drops of candle wax from the burning candle)
	or
300	2 cm styrofoam balls (any size will do)
300	toothpicks (to stick the balls together)

3.8 Cutting Crystals

In this investigation students test the particle model by cleaving crystals.

Materials

15 single-edged razor blades
15 "hammers" such as short metal rods, screwdrivers, etc.
1 large crystal of rock salt (4 x 5 cm)
1 large calcite crystal

Start them off by demonstrating how to cleave a rock salt crystal (for a joke, tell them it's a diamond). After breaking it into 15 smaller crystals, ask them if they want to try it. Tell them to make a perfect cube and bring it up to the front. When they arrive, ask them if they noticed how easily it cleaved and then send them back to their desks to make a triangular crystal. Some students succeed, but all are impressed with the extreme difficulty of the procedure. They learn to appreciate how the particle model works. Eventually, bring out the calcite crystal and show how it cleaves into different shapes along different planes. Students find this investigation especially interesting.

3.9 Crystal Sizes

NOXIOUS GAS (CS_2)

This investigation shows that crystals formed by the evaporation of a solution are larger if the evaporation rate is decreased.

Materials
30 watch glasses
15 funnels
1 dropper bottle of flowers of sulphur dissolved in carbon disulphide
4 stereo microscopes

Dissolve as much sulphur as possible in the carbon disulphide by stirring and shaking, then filter the solution. Go around the room putting a drop of the solution on each watch glass. Students should cover one of their watch glasses with the funnel. The crystals can then be examined under the stereo microscope. Make sure that everyone sees the rhombic form of the crystals, the double-ended pyramid shape. Students will make the other two forms, the monoclinic and the amorphous, later on.

3.10 Growing Large, Perfect Crystals

In this investigation students grow alum crystals using a seed crystal suspended in a saturated alum solution.

Materials
15 large baby food jars
15 250 ml graduated cylinders
15 watch glasses
15 stirring rods
thread, fine wire or hair
15 funnels
15 filter papers
400 g alum (potassium aluminum sulphate)

If tying a thread or a hair to a tiny seed crystal is too difficult for a level-one student, use fine pieces of copper wire. A 30 cm piece of lamp cord can be dissected to produce enough wire for several classes.

The next problem is to obtain a saturated solution. Some groups day after day find that their seed crystal has dissolved. Their friends may be playing tricks on them, and the solutions may have to be locked in a cupboard. Also, if the temperature in the room varies too widely from day to day or during the night, it may be simpler to have students grow the crystals at home.

If students like growing alum crystals, let them try some others, such as a chrome alum, which grows quickly and perfectly.

Finished crystals must be coated with laquer or varnish to keep the water of hydration from escaping and the crystals from crumbling into powder.

3.12 Particle Similarities

In this investigation three substances are dissolved in the same solution. As the solution evaporates, two kinds of crystals form.

Materials
15 20 x 150 mm test tubes
15 test tube holders
15 Bunsen burners
15 Petri dishes
75 g copper sulphate
75 g alum
75 g chrome alum

Alum and chrome alum particles must be very similar if both can grow on the same crystal, while copper sulphate particles, which form crystals on their own, must be quite different.

3.13 Metallic Crystals

A chemical reaction deposits copper crystals on a nail and silver crystals on a copper wire in this investigation.

Materials
30 13 x 100 test tubes
15 test tube racks
75 g copper sulphate
15 g silver nitrate
15 iron nails
15 2 cm copper wires
4 stereo microscopes

Usually the copper crystals on the nail are quite small and look like rust, but occassionally a large perfect one grows that is easily seen in the microscope. Silver crystals growing on the copper wire show up well on the projection microscope also.

CHAPTER FOUR – DENSITY

Chapter Objectives and Philosophy

Chapter four continues to develop the particle theory. Densities of solids, liquids and gases are measured and compared and the connection between density and bouyancy is examined. The particle theory explains all this and the difference between the densities of the three forms of sulphur as well.

This chapter concludes the first cycle of the scientific method. The second cycles starts over to show that heat is the motion of these tiny particles.

4.2 Size – Density

The density of wooden dowels of various lengths is calculated in this investigation. The mass is plotted against the volume to get a straight line.

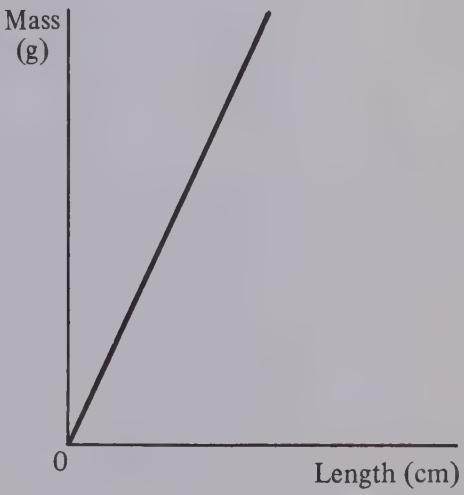
Materials

30 3/4" wooden dowels from 5 cm to 10 cm in length
(varnish to waterproof)
15 equal-arm or triple beam balances
15 100 ml graduated cylinders

The mass of the wooden dowels is fairly easy to find accurately, but the volume gives students trouble. Get them to be extra careful here. These densities will be in g/ml. There is no need to introduce kg/m^3 yet, nor the concept of slope (but do expect students to appreciate why the graph should be a straight line).

Sample Data

Mass (g)	Length (cm)
0	0
14.3	5
20.0	7
25.7	9
28.5	10
34.2	12
37.1	13



4.6 Density – Bouyancy

By the displacement of water, this investigation determines the volume of small irregular objects. The densities are calculated and compared with the density of water.

Materials
30 various objects (corks, marbles, wood blocks, coins, etc.)
15 balances
15 100 ml graduated cylinders

In 1.8 students calculated the mass of 1 ml of water. They should now know that the density of water is 1 g/ml. Those who cannot remember should either look it up or repeat the measurements.

4.7 Buoyancy in Various Liquids

The density of various liquids is calculated. A wooden stick hydrometer is dropped into each liquid and the depth to which it sinks is noted.

Materials
15 100 ml graduated cylinders
15 balances
15 weighted wooden stick hydrometers
1.5 ℓ water, oil, antifreeze, alcohol

A wooden stick hydrometer can be made from 1" by 1" by 20 cm long pine, which gives it a volume of 32.3 ml. Now weigh the stick. The total mass of the stick should be about 2/3 of its volume, so that it will float easily in water.

The total mass should be about 20 g. Drill a hole in the bottom of the stick and screw in a 2½" wood screw (which weighs about the right amount). A coat of varnish waterproofs it.

A ruler held outside the container parallel to the stick can be used to measure the amount of submerged stick to the accuracy needed here, or cement a strip of waterproof cm graph paper to the stick.

4.8 Who can float the biggest boat?

Each person makes a boat from the same size piece of aluminum foil. The object is to find out which boat can hold the most. (The one with the greatest volume and thus the smallest density.) A boat will sink just after its mass in grams exceeds its volume in millilitres.

Materials
30 10 x 10 cm aluminum foil (or larger)
2 rolls masking tape

20 10 g masses
1 large container for water (or sink)

Give students half a period to construct their boats and then hold a competition to see whose boat can hold the most. Let them add the masses one by one. Note the mass just before it sinks, not the one which makes it sink. Keep a complete record on the board. Arrange the boats in order on the front desk and ask students for their conclusions.

Larger pieces of aluminum foil (say, 15 x 15 cm) might get better results with the slower-stream students. Reinforcing each edge with a strip of masking tape helps too.

Incidentally, the biggest boat possible from a 10 x 10 cm sheet is 6.67 cm by 6.67 cm by 1.67 cm high. This is a level five calculus problem and gives a volume of 74.07 cm^3. The boat could be made into a hemisphere but would have a volume of only 67.55 cm^3.

NOXIOUS
GAS (SO_2)
FIRE

4.9 Making Monoclinic Sulphur

Materials
15 20 x 150 mm test tubes
    (save for this experiment from year to year)
15 Bunsen burners and spark lighters
300 g roll sulphur
15 funnels
15 filter paper
4 stereo microscopes

Warn students not to heat the sulpher too quickly or too long or it will turn gummy. Open the filter paper when the top surface turns from glossy to dull, indicating that it has hardened.

NOXIOUS
GAS (SO_2)
FIRE

4.10 Making Amorphous Sulphur

Materials
15 20 x 150 mm test tubes
15 Bunsen burners and spark lighters
15 250 ml beakers of cold water

Only the brave do these two investigations in a room without ventilation. Put out fires calmly with a wet paper towel or by dunking the open end of the test tube in a beaker of water. Watch out for your eyes: wear goggles.

CORROSIVE
LIQUID (tetrabromoethane)

4.12 The Densities of the Forms of Sulphur

The three forms of sulphur have slightly different densities which can be shown by means of a solution of butyl carbitol and tetrabromoethane, two dense liquids. Demonstrate this investigation, because the diagram in the text is incorrect.

Get small samples of roll sulphur (rhombic), monoclinic sulphur and amorphous sulphur (not too old). Get samples of the two liquids in dropper bottles and, starting with butyl carbitol, make a solution of the proper density.

The three sulphur samples will sink in butyl carbitol, then float as more and more tetrabromoethane is added. Be sure to add enough to make them all float. Now add butyl carbitol carefully until the amorphous sulphur floats, the rhombic sinks, and the monoclinic is suspended halfway.

Materials

1 13 x 100 mm test tube and stopper
50 ml butyl carbitol
50 ml 1,1,2,2 tetrabromoethane
3 samples sulphur of various forms

This is not recommended as a class experiment because of the nature of tetrabromoethane, a fairly dangerous substance.

Densities

rhombic	2.07 g/ml
monoclinic	1.96 g/ml
amorphous	1.92 g/ml

4.14 Gases – Mass, Volume and Density

This investigation measures the density of carbon dioxide gas produced by an Alka-Seltzer tablet.

Materials

30 Alka-Seltzer tablets
15 balances
15 100 ml graduated cylinders
15 500 ml beakers
15 250 ml beakers

Sample Observations:

A.	1. mass before fizzing	164.3 g
	2. mass after fizzing	163.7 g
	3. mass of gas released	0.6 g

B. 1. volume of gas released 110 + 100 = 210 ml

Break the tablet in half and collect each half separately. Use the same water over again to reduce the amount of gas dissolved in the water.

2. mass of gas 0.6 g

3. density of gas

$$\frac{0.6\text{ g}}{210\text{ ml}} = 0.0029\text{ g/ml}$$

$$= 2.9\text{ kg/m}^3$$

Density of CO_2 at STP $= 1.977\text{ kg/m}^3$

The major difficulties here are that gas dissolves in the water and escapes around the edges of the cylinder.

CHAPTER FIVE – HEAT AND TEMPERATURE

Chapter Objectives and Philosophy

The first four chapters have established evidence for the particle theory of matter. Students should be convinced of the suitability of a particle explanation for the structure of solids, liquids, and gases. The work on crystals and density should suggest further study on the differences in particle structure of solids, liquids and gases. Throughout these chapters occasional reference has been made to heat and the effects of heating on the properties of matter.

In chapter five, a macroscopic study of the effects of heat on matter is attempted. No efforts are made to account for these effects on a particle basis. The factors affecting the heat content of solids and liquids are investigated and the joule is introduced as the basic unit for measuring quantities of heat. The student should be able to make simple calculations of heat transferred when solids or liquids undergo temperature changes. No attempt is made to identify heat as a form of energy.

5.3 Heat – Water

ELECTRIC SHOCK (if immersion heaters used)

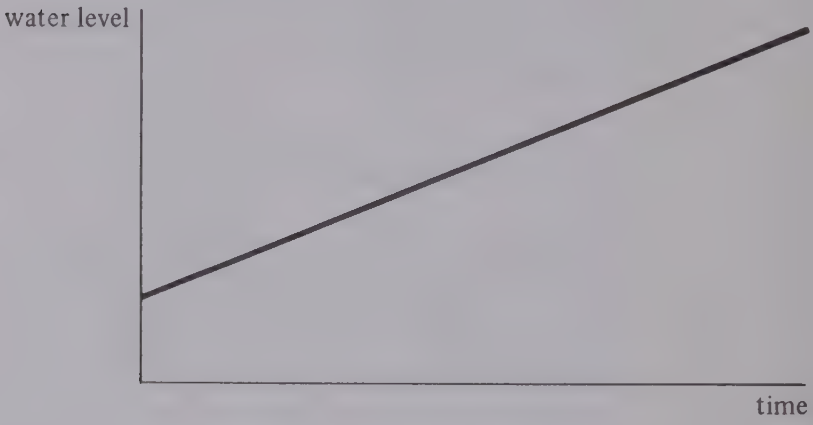
The simplest possible introduction to the thermal expansion of a liquid and the principle of the thermometer, this investigation is a good starting point for a study of heat.

Materials

15 500 ml beakers
15 immersion heating coils
15 150 ml test tubes
15 1 hole stoppers (to fit test tube)
15 pieces of glass tubing 30 cm long

15 wooden rulers
ink or food colouring
elastic bands

To avoid accidents, have the glass tubing inserted through the stoppers, (using a drop of glycerin) prior to class. Although Bunsen burners may be used throughout this chapter, immersion heating coils provide a more uniform source of heat. Be sure to use wooden rulers, since plastic ones melt, and deform badly under the pressure of the elastic bands. Immersion heaters should be turned on only when completely immersed in a liquid, since otherwise they will overheat and the coil will burn out.



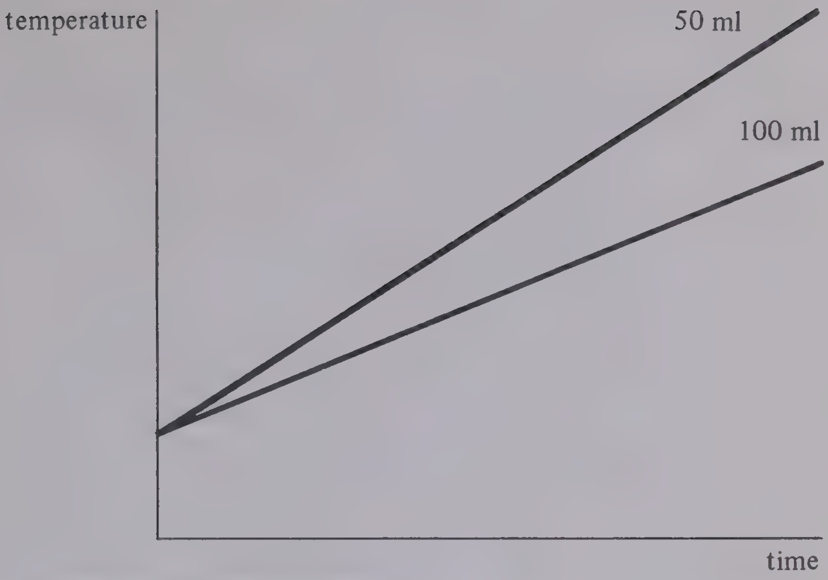
5.5 Temperature Increase/Amount of Matter

In this investigation, the effect of amount of matter on the heat required to produce a given temperature change is explored. The proportionality between heat transferred and amount of matter is reliably confirmed.

Materials
15 250 ml beakers
15 100 ml graduated cylinders
15 immersion heating coils
15 thermometers

To avoid the effects of residual heat in the apparatus, use a new beaker (at room temperature) for the second sample. Also, cool the heating coil to room temperature under the tap before beginning to heat the second sample.

The slope calculation for the rate of temperature increase usually requires some blackboard examples. Be sure the students choose straight line portions of the graph, and the slope will be very nearly inversely proportional to the mass of water being heated.

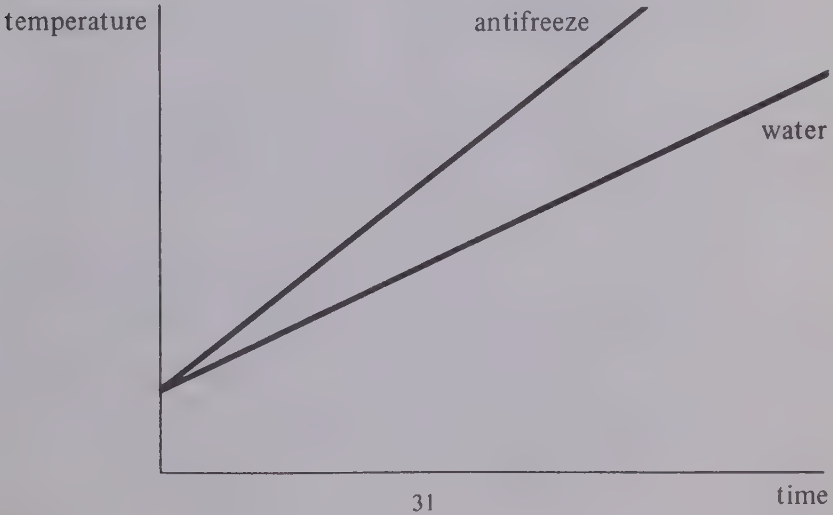


5.7 Heat and Different Liquids

The purpose of this investigation is to discover that the same amount of heat causes different temperature changes in the same amount of different liquids.

Materials
30 250 ml beakers
15 100 ml graduated cylinders
15 immersion heating coils
15 thermometers

Antifreeze may be replaced by oil or methanol if an immersion heater is used. If an open flame is used, stick to antifreeze. Once again, the slopes of the temperature-time graphs are very nearly inversely proportional to the specific heat capacities of the two liquids.



5.10 Heat Transfer in Water

The objective in this investigation is to establish evidence for the principle of heat transfer (heat lost = heat gained) when samples of water at different temperatures are mixed.

Materials
30 large styrofoam cups
15 100 ml graduated cylinders
15 thermometers

The styrofoam cups work well as crude calorimeters except for heat lost by convection. This problem can be minimized by taking the temperatures **just** before mixing and recording the **highest** temperature achieved after mixing. If only one thermometer is used, the sequence of measuring temperatures should be cold-hot-mixture.

The calculations usually are poorly done. Sample calculations on the blackboard are always helpful, since students often have difficulty with this part of the investigation. The table for recording and calculating data can be tricky so perhaps its layout can be discussed in advance.

The marginal note on page 108, an excellent challenge for scholarship students, will require basic algebra and some help from the teacher.

5.13 Heat Content of Different Metals

This simple investigation uses the principle of heat transfer to calculate and compare the specific heat capacities of various metals.

Materials
15 sets metal samples of same mass (aluminum, copper, zinc, lead, etc.)
15 styrofoam cups
15 250 ml beakers
15 thermometers
supply of boiling water and fine string

Heat lost in transferring each metal sample from the hot water bath to the cold water can be partially offset by the heat contained in the small amount of hot water which is transferred with it. Making the transfer quickly and mixing immediately are the keys to success.

The calculations can be very difficult for students. Blackboard examples and individual help are needed. Students working on the calculations in small groups often help each other more effectively than the teacher can.

If metal samples of different mass are used, the calculations will require that each sample be divided by its own mass. A table of accepted values is given on page 112.

CHAPTER SIX – CHANGES OF STATE

Chapter Objectives and Philosophy

Having studied in chapter five the changes in temperature that result when heat is added to solids and liquids, students are now exposed to the other phenomenon which can occur when heat is added to matter – i.e. a change of state. A very simplistic, non-assuming approach is taken, emphasizing even the most obvious characteristics of various changes of state. The purpose of this in-depth treatment is to allow the students to form a mental model of the three states of matter, so that they can account for the observations made in the more sophisticated investigations later in the chapter. By the end of chapter six, students should be sufficiently familiar with the effects of heat on the three states of matter to be able to appreciate, or even propose, the kinetic molecular hypothesis. Investigations in chapter six have been chosen because of their ease of explanation on a kinetic molecular basis. It may be valuable to review the discoveries of chapter six just after the moving particle theory is introduced in 7.1.

Many of the investigations are brief so that although the chapter seems lengthy, it should easily be completed as is. However, selected investigations may be omitted.

6.3 Volume-Melting

In this simple investigation the students determine whether there is a change in volume when a solid (ice) melts.

Materials

15 100 ml graduated cylinders
supply of ice cubes

Try to use ice cubes which are small enough to be submerged in a 100 ml graduated cylinder. It is a good idea to have the students calculate the ratio of

$$\frac{\text{Volume of water (from ice)}}{\text{Volume of ice}}$$

and try to relate this ratio to the density of ice and its bouyancy.

6.4 Mass – Melting

In this similar investigation the absence of change in mass after melting is discovered.

Materials

15 100 ml graduated cylinders
15 equal arm balances
supply of ice cubes

The investigation itself is very simple, but the problem posed in section 6.5, related to the results of 6.4, can be quite challenging.

The illustration unfortunately shows the ice cube floating with its total volume submerged, rather than with 1/9th of its volume above water. Students as a result may believe that ice and liquid water are equally dense, but the combined results of 6.3 and 6.4 should convince them otherwise.

6.6 Heat – Melting

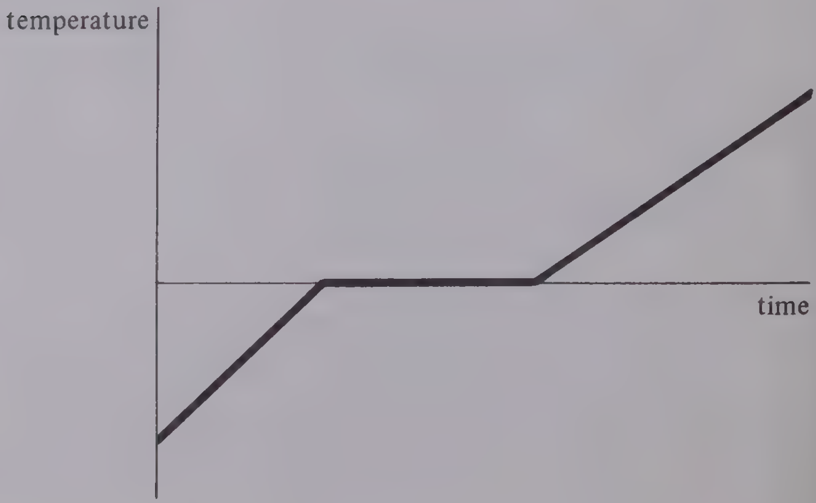
In this investigation. ice is crushed and then heated uniformly until it melts and the water heats up. The purpose is to show that temperature remains constant during melting even though heat is being added.

Materials

15 250 ml beakers
15 thermometers
15 Bunsen burners
supply of crushed ice

To derive the expected graph of temperature versus time, it is essential that the ice be stirred steadily during heating. If care is taken, the thermometer may be used as a stir stick, as long as it doesn't remain in contact with the bottom of the beaker.

The slope of the heating curve for ice should be about twice as steep as for water, because of its lower specific heat capacity. (2.1 kJ/kg • °C)



6.7 Melting Ice

In this rather ambitious investigation students determine a value for the latent heat of fusion of ice.

Materials
15 large styrofoam cups
15 equal arm balances
15 thermometers
supply of ice cubes

Better results are possible if a lid is placed on the styrofoam cup immediately after adding the ice cubes. If the lid has a small hole in it, the thermometer can be used for mixing, which will speed the melting process. The calculations usually cause some difficulty, so sample data and calculations have been included in the text. Small groups of students working together on the data can often be effective in solving individual difficulties. With reasonable care results within 10% of the accepted value (approx. 335 kJ/kg) are common.

6.9 Antifreeze–Melting Point

In this investigation the depression of the freezing point of a solution is demonstrated.

Materials
15 250 ml beakers
1½ ℓ of antifreeze (100 ml per team of 2 students)
supply of crushed ice.
Ditto fluid or methanol may be used instead of antifreeze.

This investigation, although easily performed with reliable results, presents students with a difficult concept and usually requires a great deal of class discussion. Some students might like to repeat the investigation using some other miscible liquid (alcohol) or even a soluble solid (salt or sugar).

BROKEN
GLASS

6.11 Boiling–Melting

This rather primitive investigation is designed to demonstrate that the heat of vaporization of water is much greater than its heat of fusion.

Materials
15 large **Pyrex** test tubes
15 Bunsen burners
supply of ice cubes

Perhaps the term "more difficult . . . " should be replaced by "does it take more heat . . ." since the factor being investigated is the time (and hence amount of heat) required to melt the ice and boil away the water. Although the method sounds potentially dangerous, there is no cause for concern as long as a hard-glass test tube is used and the heat is removed as soon as the last drop of liquid is vaporized.

6.13 Antifreeze–Boiling Point

Similar to 6.9, this investigation demonstrates the boiling point elevation of water when mixed with antifreeze.

Materials
15 250 ml beakers
15 Bunsen burners
15 thermometers
1 ℓ antifreeze (approx. 60 ml per team of 2 students)

As an added exercise students could plot temperature-time graphs for each concentration of water-antifreeze mixtures on the same axes. Use a time axis which is well spread-out.

BROKEN
GLASS

6.15 Boiling and Condensing – Volume Changes

This rather clever and convincing demonstration of the large increase in volume produced when water is vaporized may be done as a demonstration or as a class experiment.

Materials
15 250 ml beakers
15 Bunsen burners
15 pr. safety goggles
15 Pyrex test tubes with holders

Use only a few millilitres of water in the test tube and be certain to invert the hot test tube into the cold water as soon as the water in it is boiling freely. Safety goggles and hard glass test tubes are essential. Students may have some difficulty in appreciating what they have observed in this investigation. A good post-lab discussion is usually necessary.

6.16 Estimating Particle Size

The diagram on page 129 is not drawn to scale. Emphasize with the students the great increase in volume produced by a small increase in particle spacing. In fact, the title of the exercise should be "Estimating Particle Spacing", rather than particle size.

IMPLOSION

6.19 Boiling Point–Reduced Pressure

The lowering of the boiling point under reduced pressure offers valuable evidence for the kinetic molecular theory which is utilized in chapter seven.

Materials

15	250 ml boiling flasks
15	1-hole stoppers with thermometers to fit boiling flasks
15	Bunsen burners
15	retort stands and ring clamps

The secret to success in this investigation is to insert the stopper quickly into the boiling flask while the water boils freely. This is difficult and rather dangerous to do; oven mitts, a few paper towels, or a rag may help. In fact, many teachers prefer to do this procedure as a class demonstration.

When cold water is run over the bottom of the flask, boiling will continue (as evidenced by the appearance of bubbles of gas forming in the water) until the temperature drops to about 40°C.

When the experiment is finished, a vacuum forms in the flask making removal of the stopper very difficult. Slight heating (by the teacher only, after class) will ease the problem.

A good discussion of the reverse effect, boiling under increased pressure, should ensue since its experimental verification is too difficult and dangerous to do in the classroom.

NOXIOUS GAS (I_2 vapour)

6.21 Solid to Gas

This standard demonstration of sublimation gives clear evidence of the change from solid crystalline iodine to iodine vapour and back to finely divided solid iodine again.

Materials

15	250 ml beakers
30	watch glasses (large enough to cover beaker)
15	Bunsen burners
15	retort stands with ring clamps
15	pieces filter paper (larger than watch glasses)
	supply of iodine crystals

Students should see a faint purple tinge in the lower watch glass, evidence of the formation of iodine vapour, and then a very fine layer of small iodine crystals forming on the underside of the upper watch glass. In post-lab discussions, the passage of iodine particles through the very fine filter paper should be highlighted and some explanation of how this can occur should be given.

6.22 Solids, Liquids, and Gases

An in-depth discussion of the answers to the questions posed here is essential to the students understanding the natures of solids, liquids, and gases. Also, in devising a suitable hypothesis for the nature of heat (in chapter seven) the answers to these questions can suggest valuable evidence for the kinetic molecular theory proposed later.

CHAPTER SEVEN – PARTICLES IN MOTION

Chapter Objectives and Philosophy

By this point students should possess sufficient awareness of the properties of heat and temperature and the various effects of heat on matter to begin to form hypotheses regarding the nature of heat. The two historically significant theories – the Caloric Fluid Theory and the Moving Particle Theory (Kinetic Molecular Theory) – are introduced. Possible explanations for known phenomena are suggested for each theory.

The remainder of the chapter is devoted to investigations where the motion of particles of matter is either evident or can be easily inferred. A study of absolute zero and the Kelvin temperature scale is included, as well as references to paper chromatography, gas diffusion, Brownian motion in liquids and gases, and evaporation of liquids – all from the moving particle point of view.

By the end of chapter seven the students should be convinced that the particles of matter are always in motion (excluding absolute zero) and that the amount of motion (the term speed is intentionally avoided) is an indication of temperature. They should begin to think of all thermal phenomena in terms of particle motion.

7.3 Particle Collisions

The properties of colliding particles are studied using a marble-collision analogy.

Materials

15	short lengths of drapery track (50 cm each)
15	square cake tins
	a large supply of small glass marbles (approximately 360)
45	larger marbles or ball bearings

As the students cause the marbles to collide on the track, they should be observing the rebound directions and comparative speeds when small marbles hit large ones, and vice versa. Marble collisions are nearly elastic (about 95%). When marbles are placed in a row, students should see how motion is passed from marble to marble, in succession, as they collide. Finally, when all marbles are placed in the cake tin, students can get some idea of the collisions encountered by particles in a gas. They can also conclude that smaller particles generally travel faster than larger particles, and move further between collisions.

7.5 Particle Motion/Paper Chromatography

The motion of particles in black ink is studied by using filter paper to make a paper chromatograph.

Materials

15 100 ml graduated cylinders
1 bottle black ink, food colouring, or 15 water based felt pens in varying colours
supply of large filter paper
(large enough to construct a 1 cm by 20 cm strip)
15 paint brushes (water colour type)

A brightly-coloured chromatograph is produced and may be used to stimulate a lively discussion on why the various colours move up the paper different amounts. At this point, be willing to accept any feasible reasons, as long as they involve some dependence on particle motion.

CORROSIVE
MATERIAL
($KMnO_4$)

7.7 Particle Motion – Dissolving

This investigation is a simple observation of the process of dissolving potassium permanganate crystals in hot and cold water without any mechanical turbulence, if possible.

Materials

30 large test tubes and solid stoppers
a supply of potassium permanganate crystals
or any other soluble coloured crystal
a roll of masking tape

Try to get the temperature difference between the samples as large as possible. Emphasize the need for introducing the potassium permanganate crystals into the water with the least turbulence possible. In the post-lab discussion, be certain the students are thinking of the process of dissolving in terms of collisions between water particles and potassium permanganate particles.

CORROSIVE
MATERIAL
(HC1 and
NH_4OH)

NOXIOUS
GAS
(HC1 and
NH_3)

7.9 Particle – Gas Diffusion

The phenomenon of gas diffusion is studied and used as evidence for the motion of gas particles. Students are fascinated by the $NH_4^+ \ Cl^-$ reaction when the diffusing gases meet.

Materials

- 15 glass tubes about 50 cm long and 2 cm in diameter, with solid stoppers to fit each end
- 15 bottles concentrated HCl
- 15 bottles concentrated NH_4OH
- 30 eyedroppers
- 15 metre sticks
- 15 stop watches

If the procedure is followed carefully, a white ring of NH_4Cl (a finely divided solid) will form in the tube, slightly to the HCl side of centre, after a minute or so. Because location of the ring becomes vague a few seconds after it is formed, careful and patient observation is required. Students **may** smell the gases coming from each liquid if they waft the odours toward their noses in the proper manner. Once again the role of particle motion and particle collisions must be emphasized in explaining why the particles move down the tube. Since the diffusion rate of a gas is inversely proportional to the square root of its molecular weight the expected ratio of rates is $NH_3 : HCl = \sqrt{37} : \sqrt{17}$ or 1.4:1

BROKEN
GLASS
CORROSIVE
MATERIAL
(mercury)

7.11 Temperature – Volume of a Gas

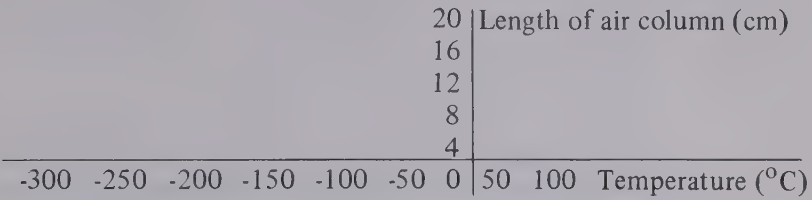
This investigation uses the relationship between the temperature and the volume of a gas to estimate a value for absolute zero. The apparatus is simple to construct and use and, with moderate care, most students can get a value for absolute zero between -260°C and -280°C. The investigation offers a valuable opportunity to test students' appreciation of the particle motion theory by allowing them to try to explain the particle motion characteristics of absolute zero. The Kelvin temperature scale is also introduced.

Materials

- 15 lengths of small bore glass tubing (about 30 cm long)
- 15 wooden rulers calibrated in millimetres
- 15 Celsius thermometers
- small supply of mercury

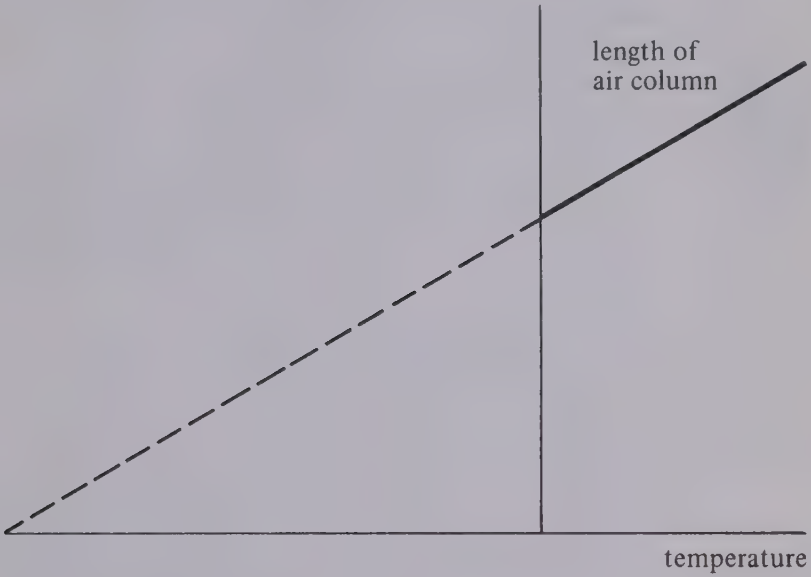
It is essential that the gas expansion tube be completely sealed. Have the students blow through the tube underwater. No hint of an air bubble should be seen. It is best if students come to one centralized area for the insertion of the mercury piston. A teacher can supervise this area and help any students who have trouble with the mercury. Ideally, the piston itself should be between 1 and 2 cm long, trapping between 4 and 8 cm of air below it. Plastic rulers melt and deform badly when the assembly is exposed to boiling water. Please note that the diagram on Page 152 fails to show the mercury piston in the tube.

The piston should be in such a position that the entire enclosed air column is below water level. Students may need some help in laying out the axes for the graph, as below:



The graph usually turns out to be quite linear and can be extrapolated to give a value for absolute zero of about -260°C. After introducing the Kelvin temperature scale, some practice in converting from Celsius to Kelvin is in order.

Students are fascinated by this investigation, even though it is quite sophisticated for grade nine. They are intrigued by the concept of absolute zero and are quite willing to discuss its implications, as far as the particle motion theory is concerned.



7.13 Liquid Particle Motion

Students in this investigation observe the erratic, molecular motion of butterfat particles as they are buffeted by molecular collisions with water.

Materials

15 microscopes
15 microscope slides
15 eye droppers
supply of homogenized milk

Students often have difficulty observing any vibratory motion of the milk globules. The motion of convection currents in the liquid is distracting. The teacher must spend considerable time helping students who have difficulty focussing in on the milk particles.

7.15 Particle Motion/Smoke in Air

A traditional observation of Brownian motion in smoke, this lab can be done effectively as a class demonstration using a projection microscope.

Materials

15	smoke cells
15	microscopes
15	light sources

When performing this investigation, care must be taken **not** to use the light source beneath the microscope stage. The smoke particles must be seen, against a perfectly black background, by light from the side reflected up into the microscope's optical system.

7.17 Particle Motion and Evaporation

NOXIOUS GAS (alcohol vapour)

In this study of the factors affecting the rate of evaporation of a liquid, the importance of an experimental control is emphasized. The point of the investigation is to explain the results in particle motion terms and account for the varying rates of evaporation.

Materials

60	250 ml beakers
15	100 ml graduated cylinders
1	electric fan
1½ ℓ	methyl alcohol

Since each evaporating sample differs from the control in only one aspect, any differences in rate of evaporation can be attributed to that fact. Results are usually excellent. Emphasis should be placed on a particle motion explanation of the results.

CHAPTER EIGHT – WORK

Chapter Objectives and Philosophy

This chapter momentarily diverts from the theme of the text to make a more traditional study of work, force and simple machines. Force and work are carefully defined and the formula for calculating work is introduced. The inclined plane, lever, and pulley are used as examples of simple machines, and the concepts of mechanical advantage and efficiency are introduced. Finally, heat, light, and electricity are identified as capable of doing work. Much of the emphasis in this chapter leads to the introduction of the concept of energy in chapter nine.

8.4 Measuring Work

The purpose of this investigation is to allow students to practise measuring forces and, using the formula, to calculate work done.

Materials
15 spring balances, calibrated in Newtons
30 blocks with hooks on one end, eyes on the other.
15 metre sticks
string

If students spend too long on this lab they become bored. Have them perform the various activities and record their data with dispatch. Issue each group two blocks and have them share them for various steps in the procedure. The exercise of pulling blocks across the table top can be used to stimulate discussion on the role of friction in doing work. Also, Newton's Law of Inertia can be discussed, as alluded to in question 4, page 168.

8.6 Simple Machines

This long, complicated investigation is designed to show the students how simple machines can be used to do work using less force and longer distances. The procedures are quite complex and the data available can be easily confused. The more complex concepts of velocity ratios, ideal and actual mechanical advantage, etc. are omitted for the sake of simplicity.

Materials
15 dynamics carts
45 metre sticks
15 spring balances
15 single pulleys
15 double-pulley assemblies
string and masking tape

Part A: **The Inclined Plane**
Spring balances give best results when used in the vertical position. When used horizontally, inverted, or on an inclined plane they give faulty readings, but we feel that using pulleys (to make all readings vertical) or correction factors cause complications which are un-

necessarily confusing. At the grade 9 level it is best to make do with the inaccurate readings. All measurements of forces which are moving should be made while the force is moving as slowly as possible, and at a constant speed. Depending on its slope, the ramp will require considerably less force than lifting the cart, but will also require that more work be done (due to friction in the wheels and between the wheels and ramp).

Part B: **First-Class Lever**
Rather than using a costly knife-edge lever for a fulcrum, a simple loop of fine string held to the underside of the metre stick by a small piece of masking tape works well. Also, the underside of the metre stick could be notched at various positions to accomodate the loop of string used as a fulcrum.

Part C: **Second-Class Lever**
In lifting the cart from its original level to the level of the top of the pile of books, cooperation between partners is required to get an accurate measurement of the distance that the force applied to the lever actually moves.

Part D: **Single-Pulley**
Check carefully to ensure that students are measuring the vertical distance the spring balance moves in calculating the work done, and not the vertical distance the dynamics cart moves. Point out, perhaps, that one is twice as great as the other, and relate this to the mechanical advantage of the pulley. Be certain that the students lift the cart slowly enough to avoid measuring any inertial forces.

Part E: **Block and Tackle**
As the concept of a machine's efficiency is introduced, a discussion of friction should naturally ensue. Any traditional lab dealing with static and/or rolling friction may be inserted effectively at this point.

8.8 Heat – Work

This investigation offers the first hint that heat is a form of energy by introducing the student to the concept of heat doing work. The demonstration of thermal expansion is fascinating and can give excellent quantitative results.

Materials
15 retort stands
15 Bunsen burners
15 sewing needles
15 microscope slides
15 protractors
supply of straws

The diagram showing the experimental set-up is a graphic, on the next page (p. 174). For accurate results, the axis of the sewing needle must be perpendicular to the axis of the retort rod. If moderate care is taken, when the rod cools, the needle will return to its original position. The action of the bimetallic strip should be demonstrated.

8.10 Work – Heat

The investigation reaffirms the fact that doing work often produces heat. It is rather trivial and could be omitted or, at least, assigned for home investigation.

Materials
15 paper clips
15 wooden blocks
15 squares of coarse sandpaper
15 test tubes with stoppers and thermometers

The exercise of shaking the test tube of water, although sound in principle, produces a small temperature increase probably due to transfer of heat from the surrounding air or hand, rather than from increased molecular agitation. A few bright students will identify this fact.

8.12 Electricity – Work

This very basic demonstration of the motor principle is not intended as an introduction to a study of electromagnetism but as a verification of the ability of electricity to do work.

Materials
15 pieces of thin copper wire (approx 1 m in length)
15 1½ V dry cell batteries
15 pr. bar magnets

The best way to construct the coils is to wind the wire around a discarded toilet tissue holder. Make certain that students don't permanently connect both ends of the conductor to the battery. Fasten one end, and just touch the other to make contact. Teachers who wish to expand this unit into a more complete study of electrostatics and magnetism might find this investigation an excellent starting point.

8.14 Light – Work

ELECTRIC
SHOCK
(light socket)

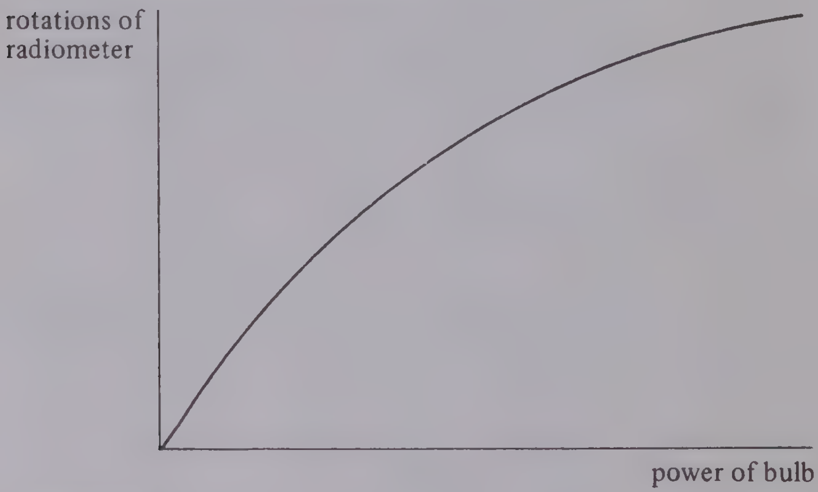
This simple, yet rewarding investigation demonstrates the ability of light to possess energy and to do work.

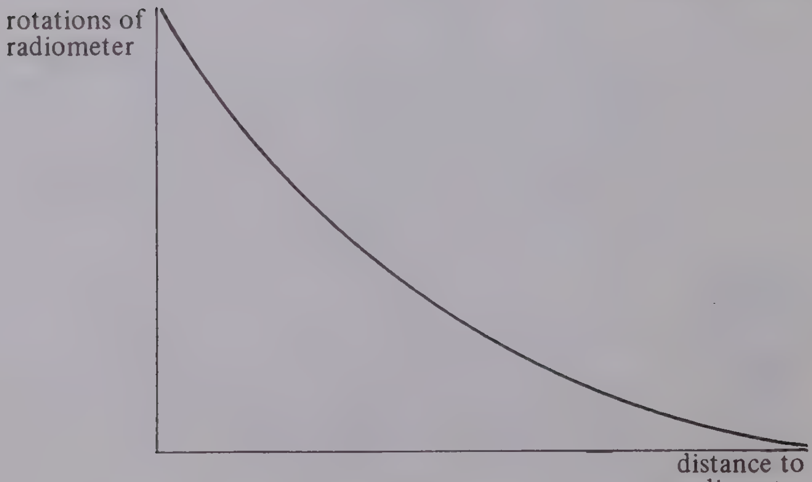
Materials

15 radiometers
15 ea lightbulbs of 25W, 40W, 60W, and 100W
15 sockets for light bulbs
15 stop watches
15 metre sticks

This lab is best performed with room lights turned off and students spread out as far as possible. Distances should be measured from the centre of the bulb to the centre of the radiometer. Some practice is required in counting the rotation rate of the radiometer, especially at short distances using the highest power bulb. A very good approximation of the inverse square law results. Teachers may wish to pursue this relationship with their ablest students.

As outlined in the text, the actual mechanism causing the vanes to rotate is thermal in nature. Better students should be introduced to this explanation and be made aware of why the vanes rotate with the dark side trailing. As confirmation they should be referred to Further Investigation 3, on page 181.





CHAPTER NINE – ENERGY

Chapter Objectives and Philosophy

The students are ready to encounter the concept of energy based on the findings of chapter eight. The main purpose of chapter nine is to define energy in terms of ability to do work, and to introduce qualitatively some simple forms of energy. Gravitational potential energy and kinetic energy are investigated and the factors affecting each are identified. Some emphasis is placed on energy conversion and the law of conservation of energy. The final sections of the chapter deal with the problem of the world's energy crisis, and introduce the students to some of the alternative forms of energy available, as well as methods of conserving our present energy resources. Teachers are encouraged to make this chapter as open-ended as they wish, venturing into the economic, political, ecological, and technology aspects of the energy crisis. The role of science in dealing with this problem cannot be overemphasized. Since chapters ten and eleven begin to look at atomic and molecular structure from a more detailed point of view, some teachers may wish to terminate this course with chapter nine.

9.3 Kinetic Energy

The purpose of this investigation is to introduce the concept of energy of motion, kinetic energy, and to make a qualitative study of the factors affecting an object's kinetic energy. No effort is made to derive or even suggest the formula at this stage.

Materials

15	pieces of drapery track (about 50 cm long)
15	wooden energy blocks (see diagram in text p.188)
15	each of three different masses of marbles or ball bearings

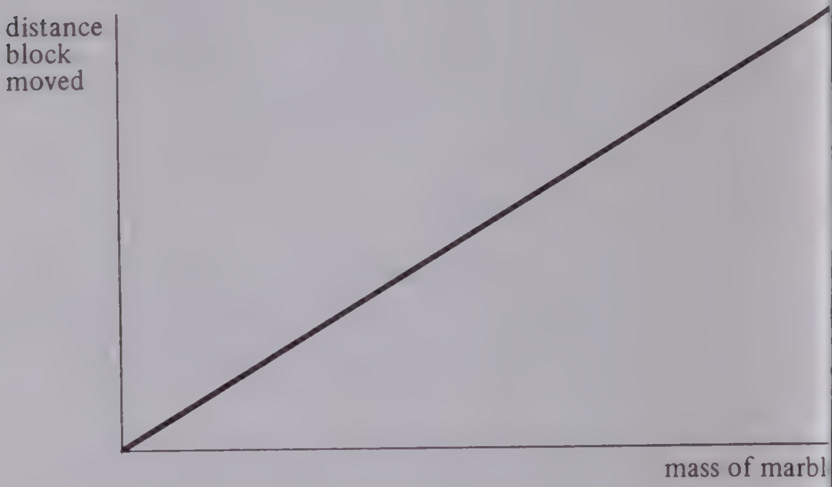
Measuring a moving object's energy by measuring the distance it will push a wooden block against the force of friction is valid, as long as the moving object doesn't rebound from the wooden block. This is easily accomplished by making the block as light as possible (use balsa wood, or at worst, cedar or pine) and the marble as heavy as possible (use steel ball bearings). Although no numerical data is reliable in this type of investigation, students should clearly see that kinetic energy is proportional to mass and velocity (although they will not be able to reveal the v^2 factor).

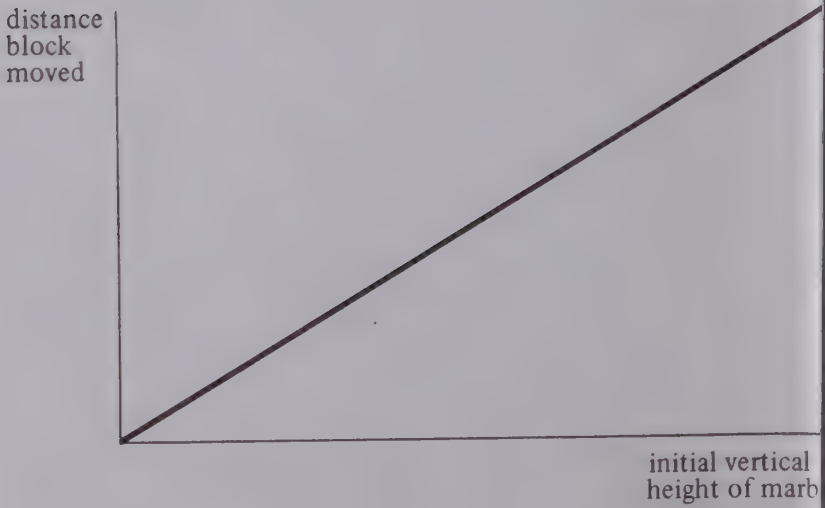
9.5 Gravitational Potential Energy

The direct relationship between gravitational potential energy and both mass and vertical height is clearly and reliably confirmed by the results of this investigation, another designed to familiarize the student with the notion of gravitational potential energy.

Materials
30 pieces drapery track (about 50 cm long)
15 wooden energy blocks
15 each of three different masses of marbles or ball bearings

Both parts of this investigation give excellent results, as long as the slope of the ramp isn't so steep that the marble jumps when it moves onto the level ramp. It is **always** a good idea to emphasize that the name of this particular form of energy is "**gravitational** potential energy" rather than the simpler, but much too general term "potential energy".





9.7 Energy Conversion

This investigation deals with the concept of conversion of mechanical energy using a simple pendulum.

Materials

15	retort stands with clamps
15	small spherical masses
	thread

Although the procedure for this experiment involves simply observing the vibrating pendulum, the questions should provoke good classroom discussion and the students can test their answers to these questions by using the pendulum they have constructed.

Some teachers may want to extend the notion of energy conversion into other than mechanical energy. The illustration of a hydro-electric generating plant on p. 190 may be a good starting point for such a discussion.

9.9 Energy in Fuel

FIRE

In this investigation the idea of stored chemical energy is developed by showing that a pre-measured quantity of alcohol contains energy and that this energy can be used to heat water. A rough calculation of the energy contained in a millilitre of alcohol is also attempted.

Materials

15	retort stands, ring clamps, and crucible holders
15	crucibles
15	250 ml beakers
15	100 ml graduated cylinders
15	10 ml graduated cylinders
50	ml alcohol (or fondue fuel, kerosene, coal oil)

Be sure to place the crucible close to the bottom of the beaker and don't worry about shielding the beaker with an asbestos gauze. A post-lab discussion should bring out the point that much of the energy from the alcohol is **not** used to heat the water, so that the calculation of energy content of the alcohol is a very low approximation.

CHAPTER TEN –
THE FORCE BETWEEN PARTICLES

Chapter Objectives and Philosophy

In previous chapters, students examined the connection between force, work, energy and heat. When work is done, energy is transferred by a force pushing something a certain distance. When the force produced a random motion of the particles of an object, we say the object gets "hot". If all the particles move in the same direction, the object just "moves".

In chapter ten, various forces are examined to find the one responsible for interaction between particles. Students look at surface tension, and forces at different temperatures, at different distances, and in solids, liquids and gases. The choice narrows to gravitational, electric and magnetic forces, and finally settles on the electric force. An investigation of the electrolysis of water tests the new hypothesis.

10.3 Forces between Soap Particles

Materials

15	wire loops
	thread
15	containers of bubble soap
15	funnels

The forces between particles act to reduce the area of the soap film to a minimum.

10.4 Forces between Water Particles

Materials

15	10 x 10 cm	wax paper
15		aluminum foil
15		paper
15	eyedroppers	
15	250 ml beakers of water	

This investigation shows that water particles are attracted to some materials and repelled by others. Can you make one water drop bounce off another?

10.6 Forces between Particles–Temperature

In this investigation students discover that the size of a drop of water depends on the temperature of the water. In hot water, the force between particles is reduced (possibly because the water molecules are further apart), and the drops are smaller. As a drop is formed, it hangs out of the end of the dropper. When the mass becomes too great, the drop falls.

Materials

15	250 ml beakers
15	eyedroppers
15	10 ml graduated cylinders

10.8 Forces between Particles–Distance

In this investigation the force of a rubber band is measured as a function of its length. One might think that the force would decrease as the distance between one molecule and another increases, but rubber band molecules are not that simple to understand. In the rubber band, they are all jumbled up, and stretching the rubber band sort of straightens them out. What students do see is that force does vary with distance. Any model must explain this.

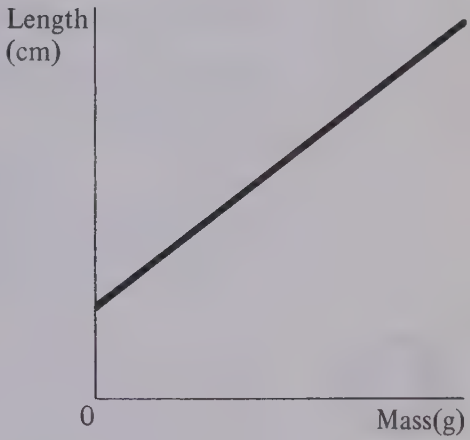
Materials

15 30 cm rubber bands
15 sets of masses and hangers
(or Newton spring balances)
15 retort stands and ring clamps
15 metre sticks

Elastic bands do not usually produce a straight line graph when force is plotted against length.

Sample Data

Length (cm)	Mass (g)
6	0
8.2	20
10.4	40
12.6	60
14.8	80
17.0	100



10.10 Forces – Gas Molecules

In this investigation a cylinder of trapped air in a syringe acts exactly like a steel spring. It resists being compressed or extended in the same way.

Materials

1 syringe (without needle)

If necessary, plug the end with your finger.

10.13 Electric and Magnetic Forces

Students are given the apparatus to do simple force experiments.

Materials

15	vinyl strips
	acetate strips
	glass rods
	ebonite rods
	wool cloths
	cotton cloths
	cat fur
	silk cloths
	strong bar magnets
	iron filings
	paper clips
	copper shot
	zinc dust

An electric magnetizer is essential when bar magnets are handled by students (who drop them, put them away backwards, etc.)

10.14 Electric and Magnetic Forces – Water

A stream of water from the tap is unaffected by a magnet but strongly attracted by a charged plastic strip, as demonstrated in this investigation.

Materials

15	vinyl and acetate strips
15	cotton and wool cloths
15	strong magnets

10.17 Electrolysis of Water

ELECTRIC
SHOCK

The electrolysis of water produces hydrogen and oxygen in the ratio of 2:1 by volume.

Materials

15	electrolysis apparatus
15	low voltage power supplies (6 – 12 volts)
	sodium carbonate or sulphuric acid
30	wooden splints

Some teachers feel more secure demonstrating this experiment.

The September 1967 issue of the Science Teacher shows an electrolysis apparatus made from stainless steel nails. Two small holes are drilled in a No. 8 solid rubber stopper. Into each hole is pressed a 2" stainless steel nail and the stripped end of a copper lead wire. Washing soda (sodium carbonate) is used as an electrolyte, instead of the more dangerous sulphuric acid. The authors of the article claim to be able to generate 35 ml of hydrogen in 15 min using a 6 volt power supply. The gas is collected in two test tubes over the electrodes.

CHAPTER ELEVEN – REACTIONS BETWEEN PARTICLES

Chapter Objectives and Philosophy

The kinetic-molecular-electric force theory of matter is tested in various chemical interactions, many concerned with rates of reaction. Students find it fairly easy to use what they have learned to predict the results of these experiments.

Included for the more advanced students is some detailed information about atomic structure, the periodic table, valences, etc., that will be meaningless to the average student. This information is meant to be only an introduction to chemistry, leaving all complexities for later years.

11.2 Chemical Reactions

FIRE (ammonium dichromate)

This investigation studies the characteristics of chemical reactions.

Materials
150 ml potassium iodide solution
150 ml lead nitrate solution
30 g ammonium dichromate
150 ml copper sulphate solution
150 ml sodium hydroxide solution
45 20 x 150 ml test tubes
15 test tube holders
15 Bunsen burners
15 10 ml graduated cylinders
15 test tube racks

Use 0.5 mol/ℓ solution: (use distilled or deionized water always).

KI	83 g/1000 ml solution
$Pb(NO_3)_2$	166 g/1000 ml solution

This produces a bright yellow precipitate.

Use a small amount of ammonium dichromate, since it expands about 10:1 to form a green powder that can fly out the end of the test tube. Fill the test tube to a depth of about 1 cm.

Use solutions as follows:

NaOH	0.5 mol/ℓ	20 g/1000 ml solution
$CuSO_4 \cdot 5H_2O$	0.25 mol/ℓ	40 g/1000 ml solution

A light blue gelatinous precipitate is formed.

CORROSIVE
LIQUID (HCl)

11.4 End-Product Amounts

The amount of hydrogen gas produced in the reaction of magnesium ribbon with an excess of hydrochloric acid is proportional to the mass of the magnesium.

Materials
15 100 ml graduated cylinders
15 250 ml beakers
2 ℓ dilute hydrochloric acid (1 mol/ℓ)
100 cm magnesium ribbon

Fill the cylinder to the brim with dilute acid, drop in the magnesium ribbon, place the beaker over the cylinder, and carefully invert. With any luck no air will leak into the cylinder. No extra water is needed in the cylinder. When the first strip is finished, the dilute acid can be poured back into the cylinder for a second, third or even fourth run.

Sample Data
37% HCl is 12 mol/ℓ. To make 1 mol/ℓ, use 84 ml of stock solution with water to make 1000 ml of solution. Our magnesium ribbon has a mass of 0.01 g/cm and produces about 12 ml/cm of hydrogen.

Length of Magnesium Ribbon	Volume of Hydrogen
2 cm	23 ml
4 cm	45 ml
8 cm	91 ml

In each case, it took about 5 min to react.

11.6 Reaction Rate – Temperature

The time it takes an Alka-Seltzer tablet to react with water is inversely proportional to the temperature of the water.

Materials
45 Alka-Seltzer tablets
15 250 ml beakers of hot water
15 thermometers

Assign each group a temperature to use and hand them a tablet. Temperatures might range from 10°C to 90°C, by tens. By adjusting the hot and cold water taps, students have little difficulty in getting the proper temperature. Their major problem is in deciding when the reaction is over, since the solution keeps bubbling (dissolved carbon dioxide?) after the tablet disappears. Tell them to stop when the last large piece of tablet disappears. The aspirin in the tablet does not react and sinks to the bottom, confusing the issue slightly. Nevertheless, the investigation works very well, with amazing results at high temperature.

11.7 Rate – Surface Area

This investigation demonstrates that as the surface area increases, the rate of reaction increases.

Materials
45 Alka-Seltzer tablets
15 250 ml beakers
15 mortar and pestles

Students time the reaction of the tablet whole, in quarters, and as a powder. There is a significant difference in the time for each.

CORROSIVE
LIQUID (HC1)

11.8 Reaction Rate – Concentration

The rate of reaction of magnesium ribbon in dilute hydrochloric acid is inversely proportional to the concentration of the solution.

Materials
45 test tubes (20 x 150 mm)
15 test tube racks
45 cm magnesium ribbon

The first test tube is filled with 10 ml of 1.5 mol/ℓ hydrochloric acid, the second with 5 ml, the third with 2.5 ml. The second and third are then filled with water to the 10 ml mark. To make 1.5 mol/ℓ dilute HC1, mix 126 ml of stock 37% HC1 with water to make 1ℓ of solution. The strips of magnesium ribbon are each 1 cm long.

Sample Data

Concentration	Time
1.5 mol/ℓ	22 s
0.75 mol/ℓ	63 s
0.38 mol/ℓ	300 s

EXPLOSION

11.9 Rate – Pressure

This investigation shows that the rate of reaction of an Alka-Seltzer tablet is inversely proportional to the pressure above the solution.

Materials
15 empty Alka-Seltzer bottles wrapped completely with transparent tape
15 Alka-Seltzer tablets

Screwing on the lid of the bottle slows down and eventually stops the reaction. Loosening the top releases some of the trapped gas (quickly) and the reaction proceeds. Goggles (and sometimes raincoats) are needed here.

ANSWER SECTION

The following pages contain answers to the questions asked during the investigations as well as in the review at the end of each chapter.

INTRODUCTION:

0.6 Review

1. The points on this graph are not on a straight line. They should be joined by a smooth curve.
2. The points on this graph lie on a straight line, which does not pass through the origin.
   (a) The cost of zero doughnuts is 8¢, which must be the cost of the box.
   (b) By subtraction in the table of values, each doughnut costs 14¢.
   (c) Six doughnuts cost 92¢.
   (d) You cannot find the cost of 120 doughnuts without extrapolation. This may not even give the right answer, since you would probably need more than one box. If 12 doughnuts go in each box, 120 would cost $17.60.
3.

x	y
6	5
8	6
10	7

This graph is a straight line with a slope of 1/2 and a y-intercept of 2.

4. This curve starts at the origin and curves slowly upwards.
   (a) 600 km/hr
   (b) 4400 km/hr
   (c) 38 s

CHAPTER ONE – DISSOLVING

1.3 Measuring – Volume

1. Students should be out less than 4 ml.
2. The average error should be about 1 ml or less.
3. Most graduated cylinders are graduated every 1 ml.
4. If the average error is much greater than one scale division, students should repeat the investigation.

1.5 Dissolving Sugar Crystals

1. Most students will say that the solution is clear and colourless, that no particles of sugar remain.
2. Ripples of more concentrated solution can be seen leaving the sugar crystal, if you look carefully. Remember, however, that the whole point of this investigation is to show how difficult it is to prove that the sugar is still there.
3. Students suggest that they should taste it (and you remind them of safety rule against tasting anything), or heat it, or any number of other methods. You can discuss with them what they think will happen when they carry out each of their suggestions.

1.9 Mass – Volume

1. The mass of three sugar cubes is about 9 g.
2. The mass shouldn't change at all if students are careful, but sometimes it may appear to change by 0.1 or 0.2 g. This may be due to drops of water lost, or defects in the balances.
3. The change in mass is very small as a fraction, approximately 0.2/9 = 2/90 = 2%.
4. Students will be about evenly split between gains, losses and no change. The gains and losses should be very small, indicating that very little, if any, real change has taken place.
5. If all the sugar is still there, the mass should remain constant.

1.10 Other Solutions

1. The filtrate and the filter paper show no signs of particles.
2. The copper sulphate solution is still blue, even after filtering. Crystals are recovered by heating.
3. The copper sulphate is still copper sulphate. The solution is the same colour, and similar crystals are recovered by careful heating.

1.13 Temperature – Solutions

1. Heat helps these materials to dissolve. You might ask students just how it helps.
2. Some heat is necessary, even if it is only the heat from its surroundings. At lower temperatures even less would dissolve.
3. Unsaturated solution.
4. Saturated, usually. The excess solute will dissolve out, leaving a saturated solution.

1.14 Solutions – Heat

1. Taking in heat
2. Absorbs heat. Some dissolving substances absorb heat as well.
3. Absorbs heat.

1.18 Review

2. pure substance – penny, nail, sugar, mercury, water
   mixture – bread, milk, air, quarter, cloud
3. (a) The sugar solution retains its mass during the dissolving of the sugar.
   (b) The sugar reappears when a drop of solution is evaporated.
   (c) As the sugar cube slowly dissolves, ripples of sugar solution appear next to it.
4. (a) 100 000 cm^3
   (b) 119 040 cm^3
   (c) 337 075 cm^3
   (d) 65 983 012 cm^3
5. (a) 100 ℓ
   (b) 119 ℓ
   (c) 337 ℓ
   (d) 65 983 ℓ
6. (a) 5000 ml
   (b) 5100 ml
   (c) 5135 ml
   (d) 1072 000 ml
   (e) 16 000 000 ml
   (f) 72 957 000 ml
7. (a) 250 ml
   (b) 512 ml
   (c) 29.36 ml
   (d) 6000 ml
   (e) 560 ml
8. (a) 200 mm
   (b) 0.2 m
   (c) 8000 cm^3
   (d) 8 000 000 mm^3
   (e) 0.008 m^3
9. (a) 16 000 m^3
   (b) 27 m^3
   (c) about 10 m^3 per student
10. 5200 cm^3
11. (a) 40 ml
    (b) 25 ml
    (c) 0.625 or 5/8

CHAPTER TWO – THEORIES OF MATTER

2.4 Did You Understand?

1. (a) continuous
    (b) particulate
    (c) continuous
    (d) particulate
    (e) particulate
    (f) continuous, unless it is a newspaper photo and you can see the tiny dots that form the picture
    (g) continuous
    (h) particulate
    (i) continuous
    (j) particulate
2. As you magnify the water, you eventually would see the particles.
3. (a) first kind, with plenty of hooks to hold them together
    (b) second kind, with no way to hook them together
    (c) third kind, with hooks to string end for end
    (d) particles shaped like little springs
    (e) glass air spider web

2.6 Solutions and Other Mixtures

1. These observations support the particle theory more than the continuous theory.

2. The substance breaks up into pieces so small that you can no longer see them.

3. The substance is thinned out so much by mixing with water that it is no longer visible. (Ask students why most substances break into smaller and smaller pieces as they dissolve.)

2.8 Volume of Mixtures

1. The volumes do not add up. Sometimes there is only 60 ml of mixture.

2. You measure the volume of the spaces between the sand particles as well.

3. It includes the space between water particles as well.

4. About 40 ml (100 - 60). This assumes that the space between water particles is small.

2.9 Volume of Solutions

1. A cylinder of 100 ml of water might seem to lose 1 - 2 ml if not shaken carefully. Water remains on the sides of the cylinder and on whatever was used to close the top of the cylinder (your hand?). Fortunately, this does not account for the large change in volume of the solution (4 - 5 ml).

2. Rock salt seems to take up less room after dissolving.

3. Particle theory.

4. The salt particles can fit between the water particles and leave less empty space between particles. Some may refuse to admit that there are spaces between water particles. This is shown in 2.11.

5. If rock salt and water particles were about the same size (and shape) then there should be no loss in volume.

2.11 Composition of Liquids

1. If matter is continuous, there should be no change in volume.
2. If matter is particulate, the volume might decrease after mixing.
3. No.
4. In ten minutes, a graduated cylinder of 100 ml of alcohol does not lose even 1 ml to evaporation.
5. Spilling may cost you a few millitres of solution. This is small compared to the 4 - 5 ml lost in the mixing.
6. You lose a bit when you pour one into the other. For this reason to pour them carefully without mixing them, measure the volume, and then mix is more convincing if done carefully.

2.14 Review

1. (a)

earth-seeking	sky-seeking	
bricks	smoke	pollen
people	clouds	dust
cars	steam	exhaust fumes
rain	odours	breath in winter

(b) The dust in the air, as well as the pollen, slowly settles out, landing on furniture or on allergy sufferers. A bouncing ball is alternately sky-seeking and earth-seeking as it bounces up and down. The fact that most objects sometimes can be in either class suggests that these are not the basic kinds of matter.

(c) The sun and the moon (and the stars) would be sky-seeking, except that the Greeks put them in a third class all by themselves.

(d) This is not a good theory. It does not explain why certain things are earth-seeking and others are sky-seeking nor is it always correct (see 1.b). It offers no hypothesis to predict what will happen to some new object, so it is quite useless.

2. (a) Newton's theory predicts that the small object will be attracted to the large lead sphere. Of course, it was.

(b) Newton's theory says that the ball is always pulled towards the earth. This force will eventually pull the ball back to the earth, unless the thrower has Herculean strength.

(c) Since the moon is smaller, its force of gravity is smaller on smoke or clouds. We know that it is not strong enough to hold on to any kind of vapour, making the moon airless, smokeless, and cloudless.

(d) The theory is useless for any kind of explanation or prediction.

3. If you mix two liquids and the volume stays the same, perhaps the particles are the same size and shape, perhaps one kind has spikes on it to keep the other particles away, or perhaps there is a force field around each particle to hold off other particles. If the volume increases during mixing, perhaps the particles of one substance repel the particles of the other substance.

CHAPTER THREE – CRYSTALS

3.5 Saturated Solutions and Crystal Formation

2. Heat was released by the crystals as they form.
3. Once "broken apart", continuous matter of similar shape would have no "memory" of its original crystal shape unless it broke into pieces. Only the particle theory explains how matter can "remember" its shape.

4. Particulate matter forms crystals by joining its particles together in even rows.
5. Crystallization and freezing are similar in several ways. In both, crystals form from a liquid, and heat is released.

3.6 Crystal Formation from Molten Materials

1. Hexagonal
2. Yes
3. The particles can hook together in only certain ways to form certain shapes.
4. The particle theory is the only theory which can explain crystallization.
5. The salt particles connect together in squares to form little cubes, and finally large cubes.
6. The particles must be able to move around so they can connect together in the right order.
7. There must be some force which holds the particles together.
8. Heat must weaken the force holding the particles together.

3.7 Using a Theory to Make Predictions

1. Two particles can be joined in only one way. Four particles can be joined in a considerable number of "regular" ways. Of course, we don't count rotations or reflections as different, and regular means you keep the same pattern of angles, such as squares, triangles, etc., for the whole figure. If you also include symmetrical in your definition for regular, then there may only be three ways to connect them: a square, a line, and a rhombus. If you count all ways with 90° or 60° angles, then there may be as many as 8 different ways. See if your class, with your help, can get them all.
2. Triangular arrangements have the least space while square arrangements have the most.
3. Six on a plane, twelve in three dimensions.
4. Most symmetrical shapes, and even some rather odd shapes, work. Look for sidewalks and driveways made from small irregular paving stones, for example.
5. Unless the particle is a multiple of the standard size particle, it will distort the crystals and spoil their shape.
6. The particles must have enough time to reach their proper position in the crystal. If not, a distorted crystal is produced.
7. Perhaps it is the shape of the particle, or else that each particle might have a certain number of little hooks on it.
8. It might be easier to cut a crystal along rows than at an angle.

3.8 Cutting Crystals

1. The particle theory.
2. A small crystal should cleave in the same way as a large one, if its planes are arranged in the same direction.
3. Many crystals cannot be cleaved, but shatter when struck.
4. Cleavage planes are parallel to planes of particles, which are usually parallel to the sides of the crystal.
5. The particle arrangement in calcite would appear to be mainly triangular.

3.9 Crystal Sizes

1. The funnel slows down evaporation.
2. The funnel slows down crystal growth.
3. Crystals grow larger when they grow more slowly.
4. Rhombic
5. Triangles
6. The particle theory. Slow growth gives the particles time to get into the proper position.

3.12 Particle Similarities

1. three
2. one
3. two
4. The alum particles are similar, but different from the copper sulphate particles.
5. No.

3.13 Metallic Crystals

1. The copper sulphate solution has changed to something else, perhaps iron sulphate. (Don't expect too many students to get this; it can be brought out in discussion, however.)
2. The silver nitrate changes to copper nitrate. The blue colour is a clue.
3. The copper comes from the copper nitrate; the silver from the silver nitrate particles.
4. If you heat the solutions, the reactions proceed more quickly, and the colour changes are more noticeable. The copper sulphate solution becomes a light yellow and the silver nitrate becomes light blue.

3.16 Review

1. TRUE Each crystal is a single colour throughout.
2. TRUE No particles can be seen.
3. TRUE Unless they hook together in rows, the crystal will not have nice straight edges and sharp corners.
4. TRUE The particles must unhook from one another during melting or dissolving.
5. TRUE Particles of various sizes could not join together to make a perfect crystal.
6. TRUE Particles of various shapes could not join together to make perfect crystals except under very special circumstances.
7. TRUE When two materials are similar enough they will go together to form a crystal. Usually, however, the two materials are so different that two kinds of crystals grow.
8. TRUE Copper sulphate seems to be an example of a material made of several kinds of particles, including copper particles.

CHAPTER FOUR – DENSITY

4.2 Size – Density

1. The density of the dowels may vary as much as 10%, but the largest is just about as dense as the smallest.
2. 0.8 g/ml, depending on the type of wood.
3. The mass of a zero volume stick is zero. Many students do not see this at first glance.
4. Straight line
5. Slow upward curve, increasing slope
6. Decreasing slope
7. Straight line with much greater slope

4.6 Density – Buoyancy

1. It will float if its density is less than one.
2. 1 g/ml or 1000 kg/m^3
3. Ice floats, therefore it is less dense than water.
4. Less dense
5. Less dense, when filled with helium.

4.7 Buoyancy in Various Liquids

1. Wood is less dense than water, if it floats.
2. water 1.0 g/ml
   ethylene glycol 1.12 g/ml
   methyl hydrate 0.793 g/ml
   oil 0.9 g/ml
3. The stick sinks the most in the least dense liquid and the least in the most dense liquid.
4. Drop the stick in the unknown liquid and measure the depth to which it sinks. Read off the graph the density which corresponds to that depth.
5. The density of water is exactly 1 g/ml (at 4°C).
6. The liquid was less than the stick.

4.8 Who Can Float the Biggest Boat?

1. A floating boat is less dense than the water.
2. The boat with the least density will win. Since all the boats have nearly the same mass, it means that the boat with the greatest volume wins.

4.12 The Densities of the Forms of Sulphur

1. They are all less dense than tetrabromoethane.
2. They are more dense than butyl carbitol.
3. The rhombic is the most dense and the amorphous is the lease dense.
4. The particles are packed most closely in the rhombic.
5. The spaces between particles must be largest in the amorphous.
6. If sulphur were continuous, all three forms would have the same density. There are no holes between particles.

4.17 Review

1. (a) 3.1 g/ml
   (b) 1.71 g/ml
   (c) 1.000 g/ml
   (d) 0.00034 g/ml
   (e) 1600 kg/m^3
   (f) 1176 kg/m^3
   (g) 10996 kg/m^3
   (h) 2000 kg/m^3
2. (a) is (d)
   (b) is (c)
3. (a) 567 cm^3
   (b) 567 ml
   (c) 0.739 g/ml
   (d) 739 kg/m^3
   (e) It will float because it is less dense than the liquid
4. The density of the ship is less than that of water because of the large amount of air inside it. The air adds volume but very little mass. This lowers the density of the ship.
5. If the ship were filled with enough mass, the density would be more than 1000 kg/m^3 and it would sink.
6. Butter floats in both. (density 0.915 g/ml) (melting point 15-17°C)
7. Nickel floats easily in mercury (see chart on page 95)
8. You must be slightly less dense than water (0.9179 g/ml at 15°C is the density of human fat).
9. (a) 35 000 cm^3
   (b) 35 000 ml
   (c) 0.035 m^3
   (d) 8.96 g/ml
   (e) 8960 kg/m^3
   (f) copper
10. 17 kg
11. 0.595 kg
12. 2.5 m^3
13. 58.8 ml

CHAPTER FIVE – HEAT AND TEMPERATURE

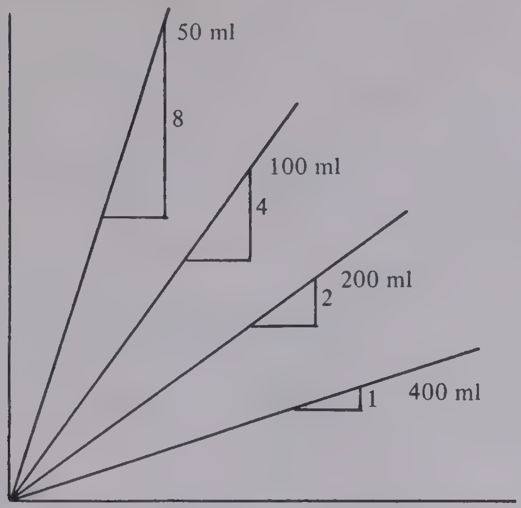
5.3 Heat–Water

1. The shape of the graph is a straight line with a positive slope which indicates that the constant source of heat causes a uniform increase in volume.
2. As heat is added to the water, the particles move farther apart, thereby occupying more space each. The water therefore has a greater volume.
3. The thermometer employs the principle of thermal expansion of a liquid.
4. Mercury and alcohol are more suitable than water. Mercury freezes at -39°C and boils at 357°C, alcohol freezes at -98°C and boils at 65°C. Thus both have a greater temperature range than water.

5.5 Temperature Increase – Amount of Matter

1. In both cases, the temperature increased uniformly, as indicated by the straight lines on the temperature-time graph.

2. For the 50 ml sample, the rate should be twice as great as the 100 ml sample, and for the 400 ml sample, the rate should be only 1/2 as great as the 200 ml sample.



3. Time to heat is directly proportional to mass heated (if temperature change is the same).

$$\therefore \text{time for } 120 \text{ ml} = 6 \text{ min} \times \frac{120 \text{ ml}}{80 \text{ ml}}$$
$$= 9 \text{ min}$$

4. The amount of heat necessary to produce a given temperature change is directly proportional to the mass being heated.

$$H \propto m \text{ for given } \Delta T$$

5.7 Heat – Different Liquids

1. Neither; they each receive the same amount of heat from the coil.
2. The two liquids have different abilities to hold heat without their temperature increasing – called their heat capacities.
3. Water has a greater heat capacity than antifreeze since it takes more heat to change the temperature of water than of an equal mass of antifreeze.

5.8 Exercise – Quantity of Heat

1. $H = m \times \Delta T \times C$
   $= (0{\cdot}015 \text{ kg})(20^\circ\text{C})(4.2 \text{ kJ/kg}\cdot{}^\circ\text{C})$
   $= 1.3 \text{kJ}$ gained
2. $H = 4.0$ kJ gained
3. $H = 12.6$ kJ lost
4. $H = 6.0$ kJ lost
5. $$\Delta T = \frac{H}{M \times C}$$
   $$= \frac{1.890 \text{ kJ}}{(0{\cdot}010 \text{ kg})(4.2 \text{kJ/kg}\cdot{}^\circ\text{C})}$$
   $= 45^\circ\text{C}$ increase
6. $\Delta T = 10^\circ\text{C}$ increase

7. ΔT = 5°C decrease

8. ΔT = 16°C decrease

9. $$C = \frac{H}{M \times \Delta T} = \frac{3.000\ \text{kJ}}{(0.050\ \text{kg})\ (20^\circ\text{C})} = 3.0\ \text{kJ/kg}\cdot{}^\circ\text{C})$$

10. $C = 2.4\text{kJ/kg}\cdot{}^\circ\text{C})$

5.10 Heat Transfer in Water

1. The amount of heat lost by the hot water should be greater than the amount gained by the cold water since some is invariably lost to the surroundings by conduction and convection.

2. (a) $\Delta T_{cold} = \Delta T_{hot}$ ∴ final temperature = 40°C
$2\,x = 60^\circ C$
$x = 30^\circ C$

(b) $\Delta T_{cold} = 2\,\Delta T_{hot}$ ∴ final temperature = 30°C
$3\,x = 60^\circ C$
$x = 20^\circ C$

(c) $\Delta T_{cold} = 3\,\Delta T_{hot}$ ∴ final temperature = 25°C
$4\,x = 60^\circ C$
$x = 15^\circ C$

5.13 Heat Content of Different Metals

1. See table page 112, for metals used.
2. See table page 95, for metals used.

If all samples have the same mass, then their densities are in the reverse order of their volumes.

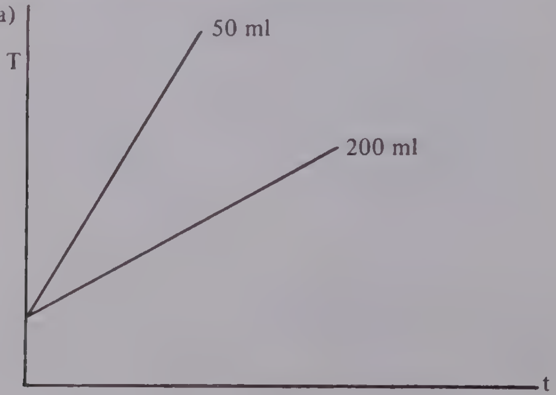
3. The most dense metals seem to have the lowest heat capacities, and the least dense have the greatest capacities.

4. The differences between classroom values and published values are due to experimental errors in the classroom. Some of these might be in measuring the mass of water, temperatures of hot water and final mixture, and, to a greater degree, not accounting for heat lost during the transfer of the metal sample.

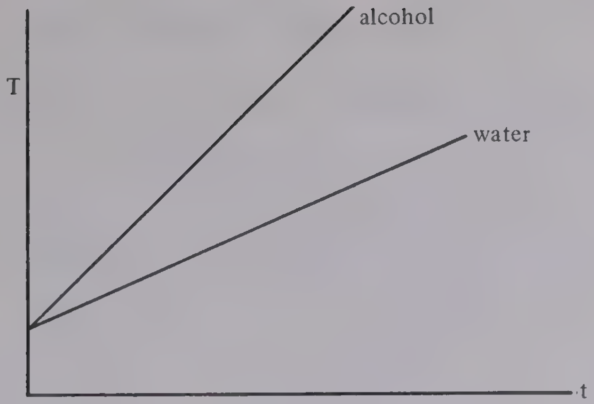
5.17 Review

1. A swimming pool on a hot summer day contains more heat than a cup of hot coffee. However, because it has such a large mass, the amount of heat shared by each of its particles is less than that for the particles in a cup of coffee.

2. (a)



(b)



3. (a) $$\begin{aligned} H &= m \times C \times \Delta T \\ &= (0.100\ \text{kg})\ (4.2\ \text{kJ/kg}\cdot{}^\circ\text{C})\ (-20^\circ\text{C}) \\ &= -8.4\ \text{kJ} \end{aligned}$$

(b) $$\begin{aligned} H &= m \times C \times \Delta T \\ &= (0.250\ \text{kg})\ (4.2\ \text{kJ/kg}\cdot{}^\circ\text{C}))(80^\circ\text{C}) \\ &= 8.4\ \text{kJ} \end{aligned}$$

(c) $$\begin{aligned} H &= m \times C \times \Delta T \\ &= (0.100\ \text{kg})\ (0.9\ \text{kJ/kg}\cdot{}^\circ\text{C}))(80^\circ\text{C}) \\ &= 7.2\ \text{kJ} \end{aligned}$$

4. (a)
$$\begin{array}{lll} 50\ \text{ml at } 15^\circ\text{C} : & (.05)\ (4.2)\ (15) & = 3.15\ \text{kJ} \\ 150\ \text{ml at } 55^\circ\text{C} : & \underline{(.150)\ (4.2)\ (55)} & = \underline{34.65\ \text{kJ}} \\ 200\ \text{ml} : & & \ 37.8\ \text{kJ} \end{array}$$
$$T = \frac{37.8}{(.200)\ (4.2)} = 45^\circ\text{C}$$

(b)
$$\begin{array}{lll} 100\ \text{g at } 5^\circ\text{C} : & (.100)\ (4.2)\ (5) & = 2.1\ \text{kJ} \\ 20\ \text{g at } 77^\circ\text{C} : & \underline{(.02)\ (4.2)\ (77)} & = \underline{6.5\ \text{kJ}} \\ 120\ \text{g} : & & \ 8.6\ \text{kJ} \end{array}$$
$$T = \frac{8.6}{(.12)\ (4.2)} = 17^\circ\text{C}$$

(c)
$$\begin{array}{lll} 50\ \text{g at } 10^\circ\text{C} : & (.05)\ (2.3)\ (10) & = 1.15\text{kJ} \\ 80\ \text{g at } 75^\circ\text{C} : & (.08)\ (2.3)\ (75) & = 13.8\ \text{kJ} \\ 130\ \text{g} : & & \ 14.95\ \text{kJ} \end{array}$$
$$T = \frac{14.95}{(.13)\ (2.3)} = 50^\circ\text{C}$$

5. In winter, water retains a lot of heat from the warmer days of summer, and releases this heat during the colder days of winter, thus moderating the climate. Similarly, in summer it takes a very large amount of heat to warm up the water, so that its temperature is usually below the temperature of the surrounding area.

6.
$$C = \frac{H}{M \times \Delta T} = \frac{0.840\ \text{kJ}}{(0.05\ \text{kg})\ (40^\circ\text{C})} = 0.42\ \text{kJ/kg}\cdot{}^\circ\text{C})$$

CHAPTER SIX – CHANGES OF STATE

6.3 Volume – Melting

1. Yes. The volume of an ice-cube decreases as it melts.
2. No matter has been added or removed from the graduated cylinder during the process of melting.
3. For the volume to change, the distance between the particles must change. As the ice melts, its particles must move closer together so that the total volume is less.
4. 100 ml of ice melts to produce about 90 ml of water.
5. The illustrations referred to in this question were inadvertently omitted from the text when printed.

6.4 Mass – Melting

1. After melting, 100 g of ice should produce 100 g of water: the mass remains the same.
2. Since mass is a measure of the number of particles and since no particles were added or removed during melting, the mass should remain constant.
3. Mass is a better way to measure an amount of matter since it remains constant. Volume changes with temperature, pressure, or the physical state of the matter.

6.6 Heat – Melting

1. Ice absorbs heat as it melts.
2. The heat needed to melt the ice comes from the surroundings – the beaker, the air, or a Bunsen burner flame, if used.
3. The heat is used to break the particles apart (in the solid state) so that they may become liquid particles.
4. If the water did start to warm up, the remaining ice would absorb this heat from the water, until all of the ice has melted. Then additional heat would cause the water to warm up.
5. Ice melts at 0°C and water freezes at the same temperature.
6. If a pond has ice floating on it, the water temperature will be very close to 0°C.
7. Before the temperature of a pond can drop below 0°C, all of the water in the pond must be frozen. Then additional cooling will cause the temperature of the ice to drop below 0°C.

6.7 Melting Ice

1. About 336 J of heat are required to melt 1 g of ice; similarly, 336 000 J or 336 kJ of heat would be needed to melt 1 kg of ice.
2. We assumed that the temperature of the ice cube was 0°C just before it was dropped into the hot water. Thus, we assumed no heat was used in warming the ice cube up to its melting point. In fact, if the ice cube was taken from a freezer, its temperature was probably about -10°C.

6.9 Antifreeze – Melting Point

1. When room temperature antifreeze is added, the temperature falls because heat is used up making the water (ice) particles and antifreeze particles harder to stick together.
2. Adding antifreeze to water lowers its freezing point.
3. If you place a mixture of antifreeze and water in a freezer at 0°C, it will not freeze.
4. Antifreeze has its name because when mixed with water, it makes it more difficult for the water particles to stick together (and hence freeze).

6.11 Boiling – Melting

1. The greatest volume change takes place during boiling.
2. Boiling requires considerably more heat than melting.
3. It takes between 6 and 7 times as much heat to boil water as it does to melt an equivalent amount of ice. (approx. 2260 kJ/kg)
4. The distance between water particles changes most during the process of boiling.
5. During a change of state, the heat absorbed is used to increase the distance between particles and cause them to become freer of one another.

6.13 Antifreeze – Boiling Point

1. Sort of. The addition of antifreeze to water causes the boiling point of the solution to be raised.
2. As the concentration of antifreeze is increased, the boiling point increases also.
3. The presence of antifreeze seems to hinder the change from water to steam.
4. The presence of antifreeze seems to help the change from ice to water.

6.15 Boiling and Condensing – Volume Changes

1. The experiment should be repeated with cold water to show that it was the presence of steam in the test tube which caused the water to rise the first time.
2. Air is trapped in the cool test tube, keeping the water from rising.
3. The bubbles in the boiling water are filled with water vapour, or steam.
5. There is a large change in volume when steam condenses to form water. The particles in condensing come much closer together, and there is a significant decrease in volume.
6. Steam and water consist of the same particles, but in water these particles are much closer and are stuck together rather loosely.

6.16 Estimating Particle Size

Particle Spacing	Volume
d	d^3
2 d	$8 d^3$
3 d	$27 d^3$
4 d	$64 d^3$
5 d	$125 d^3$
6 d	$216 d^3$
7 d	$343 d^3$
8 d	$512 d^3$
9 d	$729 d^3$
10 d	$1000 d^3$
11 d	$1331 d^3$
12 d	$1728 d^3$

Thus when water is boiled to become steam, the spacing of water particles increases by between 11 and 12 times.

6.19 Boiling Point – Reduced Pressure

1. Temperatures as low as 30°C - 35°C can be attained, with fairly vigorous boiling, if done carefully.
2. Just before the flask was plugged, most of the space above the boiling water was occupied by steam, and very little air.
3. As the sealed flask was cooled, much of the steam above the water began to condense.
4. As this steam condenses, a vacuum remains over the surface of the liquid. The more the steam cools and condenses, the less pressure there is on the surface of the liquid in the sealed flask.
5. At very high elevations (mountain tops, etc.) atmospheric pressure would be constantly lower than normal. As a result, water would boil at a lower temperature, and foods normally boiled in water would have to be cooked for a longer time to ensure thorough cooking.
6. Also, increased pressure on the surface of a liquid should cause the boiling point to increase. Car radiators, pressure cookers, and sterilizers all make use of this principle to achieve water temperatures well in excess of 100°C without boiling.

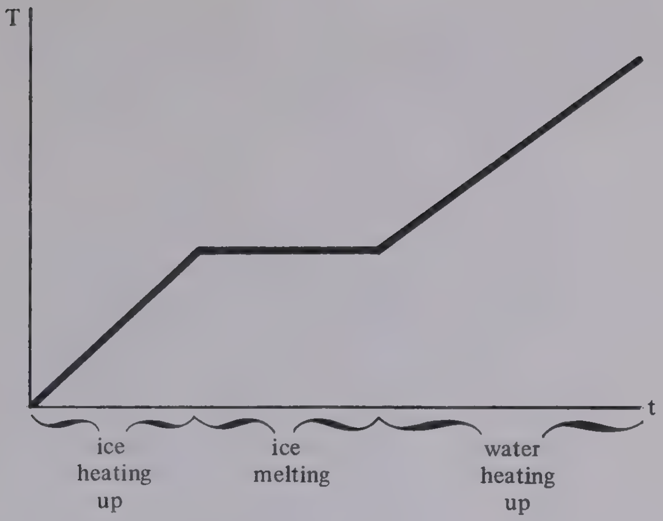
6.21 Solid to Gas

1. If ice were to sublime, it would change directly from a solid to water vapour without the appearance of any liquid water.
2. Among the three states of matter, six different changes of state are possible.
3. In sublimation, heat is added to the solid particles causing them to break completely apart, and become free of each other and spaced widely apart, which is characteristic of gaseous particles. The same type of explanation, involving particle spacing and particle adherence, can be proposed for all the other changes of state.

6.25 Review

1. boiling
   melting
   freezing
   condensation
   sublimation (2)

2.



3. (a) heat needed to melt ice cube
(0.005kg) (335 kJ/kg) = 1.675kJ
(b) heat left to warm up water
2.100 - 1.675 = 0.425 kJ
(c) $T = \frac{H}{m \times \Delta T} = \frac{0.425}{(.005)\ (4.2)} = 20°C$
(d) The same amount of heat which was released, i.e. 2.1 kJ.

4. Antifreeze is mixed with water in automobile engines to produce a cool-and with such a low freezing point that it will remain a liquid on even the coldest days. Pure antifreeze freezes at -17°C, and would solidify at that temperature.

5. To boil, the particles of a liquid need enough heat to break completely away from each other and move very far apart. To melt, the particles don't need to become as free of each other nor do they have to move as far apart. Thus it takes less heat to melt 1 g of water than to boil it.

6. On such a cold day, the water in the wet clothes quickly freezes. Then winds blowing through the clothes encourage sublimation of the ice which becomes water vapour particles that are swept away. Soon the frozen clothes are dry without becoming wet in the process.

CHAPTER SEVEN – PARTICLES IN MOTION

7.3 Particle Collisions

1. When a small marble is hit by one which has a greater mass, it moves away faster than the incoming marble.

2. When a large marble is hit by one which has a smaller mass, it moves away slower than the incoming marble.

3. The shooter marble follows along if it has a greater mass than the target marble, and rebounds back if it has a smaller mass.

4. No! Each of the particles in the sugar crystal will move. This type of collision resembles the situation when a shooter marble collides with a row of stationary target marbles.

5. Metal particles at the end of the rod which is in the flame begin moving very fast and colliding with their neighbouring particles, causing them to move faster, and hence be hotter. These, in turn, collide with their neighbours,

and the process continues down the metal rod until the particles at the far end are moving faster and hence appear warmer.

6. The marbles in a cake tin best represent a gas, since they ressemble particles which are relatively free to move in any direction and to collide randomly and chaotically with the other moving particles.

7.5 Particle Motion – Paper Chromatography

1. Collisions between water particles in the graduated cylinder caused some water particles near the filter paper to be pushed up into the spaces between the paper particles comprising the strip.
2. The various substances on the filter paper usually can be differentiated by colour. The lighter, faster-moving particles are carried further up the strip than the heavier, slower-moving particles.
3. If each coloured section were cut out, dissolved in water, and then combined, the original ink in dilute form should reappear. Most of the particles comprising the original ink would be recovered, but in a much weaker concentration.
4. If very hot water had been used, the chromatograph would have been produced faster and the bands of colour would have been wider.

7.7 Particle Motion – Dissolving

1. The potassium permanganate dissolves and spreads out much faster in the test tube containing the hot water.
2. As fast-moving water molecules collide with the potassium permanganate crystal, small groups of potassium permanganate molecules are broken off in the collisions. These continue to break down and are buffetted about by more collisions with water molecules until they have spread out uniformly throughout the water.
3. In the hot water the collisions are more violent and more frequent. Thus the potassium permanganate molecules move faster and farther between collisions, and spread out in a shorter time.
4. The crystal was introduced as it was to ensure that all dissolving occurred due to random molecule collision and not due to turbulence in the water, or by friction as the crystal fell from the surface of the test tube to the bottom.
5. By shaking and stirring the test tube the collision frequency would increase greatly, thus ensuring a faster rate of dissolving and spreading out of the potassium permanganate.

7.9 Particle – Gas Diffision

1. The appearance of the white cloud of smoke (ammonium hydroxide) indicates that the two gases, moving from opposite ends of the tube, have met and reacted, according to the following equation:

$$HC1 + NH_3 \longrightarrow NH_4Cl$$

2. Since the white cloud forms closer to the HC1 end, we can conclude that the NH_3 gas moves faster.
3. The gas particles move down the tube because they are constantly moving, colliding with each other, and being pushed apart by the collisions. Smaller, faster-moving gas particles should diffuse faster than heavier, slower-moving gas particles. NH_3 gas particles must be smaller and less massive than HC1 gas particles.

4. As the temperature of a gas increases, its rate of diffusion increases also because its particles are moving faster at a higher temperature, colliding more often and more violently, and hence being pushed further apart by the collisions.
5. The gases would diffuse faster, since there would be no interfering collisions with moving air particles already in the tube.

7.11 Temperature – Volume of Gas

1. The graph of length of air column versus temperature is a straight line sloping up to the right. The length of this air column could be used as a measure of the temperature of the air inside it.
2. Yes. By extending the graph as a straight line in either direction, its length at any other temperature (above or below those used in the lab) could be estimated.
3. Even if the graph is slightly curved, try to extrapolate these values using the "best" straight line possible.
4. As the temperature of a gas decreases, its particles move slower, colliding less often and with less force. Thus the particles are not pushed as far apart in these collisions, and as a result occupy a smaller volume of space. Theoretically, the shortest length possible would be zero, where the particles occupy no space at all. This temperature would be found where the extended graph crossed the horizontal (temperature) axis, and should be about -265°C to -275°C.
5. At this temperature, all of the particles would be stationary and no collisions would be occurring. Since temperature is a measure of particle motion, and since the particles can not have any less motion than when they are stopped, it is not possible to achieve a lower temperature than this point.
6. On the Kelvin scale, the boiling point of water is 373 K and the freesing point of water is 273 K. For any other temperature, the reading in Kelvins may be obtained by adding 273 to the reading in degrees Celcius, for example:

17°C = 290 K
-30°C = 243 K

Note: there is no period, or degree sign (°) used with the Kelvin scale; its abreviation is K, read "Kelvins", not °K, read "degrees Kelvin".

7.13 Liquid Particle Motion

1. The tiny butterfat particles, large enough to be seen under the microscope, are being buffetted on all sides by collisions with smaller fast-moving water particles. This uneven bombardment causes them to vibrate. In hot milk, the water molecules are moving faster, colliding more forcefully with the butterfat particles and causing more violent vibrations.
2. Since the water molecules are much smaller than the butterfat particles, they resemble very small shooter marbles hitting very large target marbles. In such cases, we found that the shooter marble rebounds and the target marble moves forward very slowly.
3. The milk was diluted with water to make the motion of the butterfat particles more easily visible under a microscope. Undiluted milk is too thick.

7.15 Particle Motion – Smoke in Air

1. No! The motion of the smoke particles is random and chaotic. There is always some gross motion superimposed on the random vibratory motion due to convection currents within the smoke cell.

2. The small smoke particles are constantly colliding with fast-moving air particles which cause this random motion.
3. At colder temperatures, the vibrations of the smoke particles would have been less pronounced and less frequent.

7.17 Particle Motion and Evaporation

1. One of the beakers was labelled "control" and left under normal conditions so that the amount of evaporation from all of the other containers could be compared with it. Since each differed from the control in only one aspect, any differences in evaporation could be attributed to that aspect.

2.

More Evaporation	less evaporation
# 2 air movement	# 1 cold water
# 4 alcohol	# 5 graduated cylinder (surface area)

3. #1: Since the water was cold, its particles were moving slower, on the average, and fewer of them were able to gain sufficient speed through collisions with neighbouring particles to break through the surface of the liquid and become a gaseous particle.

#2: As water particles evaporate, the air above the surface of the water gets laden with water vapour (high humidity), making it very difficult for other water particles to evaporate. A fan next to the beaker blows this humid air away, replacing it by dryer air, and more water vapour particles can be held as they evaporate.

#4: The particles of alcohol hold onto each other less strongly than water particles do, so at a given temperature, more alcohol particles are moving fast enough to break through the surface of the liquid and become alcohol vapour.

#5: Before a liquid particle can evaporate, it must be located at the surface of the liquid. Since the exposed surface area in a graduated cylinder is much smaller than in a beaker, fewer water particles are in a position to evaporate.

4. Clothes on a line will dry fastest on a warm, dry windy day when they are spread out as far as possible (... and even faster if washed in alcohol!).

7.20 Review

1. Caloric Fluid Theory: Heat is a substance which flows into or out of objects causing them to heat up or cool down. This fluid accumulates around the particles of a substance, and the degree of concentration is related to temperature.
Particle Motion Theory: The particles of a substance are continually moving, and this motion is related to the heat contained in an object. The amount of motion of a particle is directly related to the temperature of the substance.
2. In dense metals, the particles are heavy and packed tightly together. From a caloric fluid point of view, there is not much room around these particles in which caloric fluid can accumulate, and thus the heat capacity is low. From the particle motion point of view, since the particles are large and tightly packed, only a small amount of motion is possible due to collisions with neighbouring particles. Hence the heat capacity is low.
3. Ink may be separated into its component substances using paper chromatography. Biologists and chemists can use this technique to analyse complex substances by separating them into simpler components which may be identified more easily.

4. The process by which a gas spreads out from a region of high concentration is called diffusion. Examples are: odours from perfumes and deodorants; cooking odours from the oven, smoke from a chimney spreading out and becoming invisible.

5. When inflated tires are hot, the air particles inside the tire are moving faster and therefore pushing harder on the walls when they collide. This results in a greater air pressure. Thus the hot air pressure quoted would be higher.

6. If some gas is left in the can and the can is incinerated, these gas particles move very fast, causing a tremendous pressure to build up inside the can. Explosion of the can almost always occurs. If the can is completely empty (no liquid or gaseous propellant), there is no danger of such an explosion.

7. (a) 100°C = 373 K
(b) 0K = -273°C
(c) 37°C = 310 K
(d) 273 K = 0°C
(e) 20°C = 293 K

8. Mercury left open to the air will evaporate and produce harmful mercury vapour which may be inhaled and remain in the body. If the surface is coated with a thin layer of water, only the water evaporates, and the mercury remains in liquid form.

9. Alcohol evaporates quickly when exposed to the air. To do so, it requires enough heat so that its particles are moving fast enough to become gas particles. Alcohol particles absorb this heat by collisions with the particles of the skin, which thereby move slower and hence are cooler. The body cools by the same process, involving the evaporation of perspiration (rather than alcohol) from the skin.

CHAPTER EIGHT – WORK

8.4 Measuring work

1. As objects are pulled or lifted slowly, the value of the force acting on them should remain constant.

2. A force must be exerted on the block just to slide it across the table to overcome the frictional forces between the block and table which resist its motion. If the force is removed, this frictional resisting force will quickly bring the block to rest.

3. The factors which seem to affect the force needed to slide a block across a table are: mass of block, smoothness of table, smoothness of block, surface area in contact. The force could be reduced by applying a lubricant to the two surfaces, and using the minimum area in contact.

4. If friction could be eliminated, it would take **no force** to keep the block moving, once it was started. Therefore, **no work** would need to be done on the block to keep it moving across the table. Work would have to be done, though, to get the block moving in the first place, since a force would have to be applied over a measurable displacement.

5. Generally, piling the blocks on top of one another is the method encountering the least amount of friction.

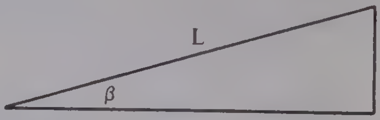
8.6 Simple Machines

Part A: Inclined Plane

1. Lifting the cart straight up requires more force.

2. For a perfectly smooth ramp, the mechanical advantage is given by:

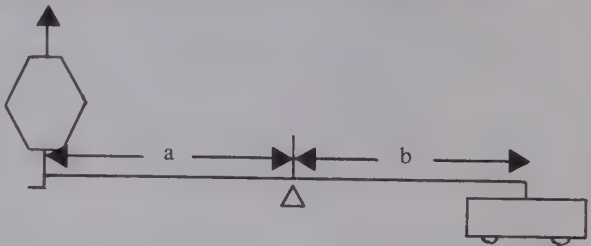
$$\text{M.A.} = \frac{L}{h} = \csc\beta$$



3. Although the amounts of work should be equal, using the ramp usually requires slightly more work, due to friction between the cart and ramp which must be overcome.
4. The ramp makes the work "easier", since it can be done using a smaller force, and applying the force over a greater distance.
5. As the ramp gets longer, its mechanical advantage increases.

Part B: First-Class Lever
1. Once again the work should be the same, but, due to friction in the fulcrum, the use of the lever requires slightly more work.
2. The lever requires less force than lifting the cart straight up.
3. For a rigid frictionless first-class lever, the mechanical advantage is given by:

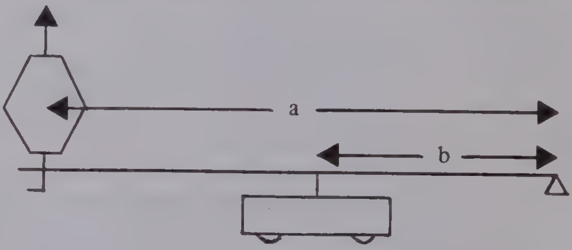
$$\text{M.A.} = \frac{a}{b}$$



4. As the distance from the fulcrum to the applied force (a) increases, the mechanical advantage increases also.

Part C: Second-Class Lever
1. For a rigid frictionless second-class lever, the mechanical advantage is given by:

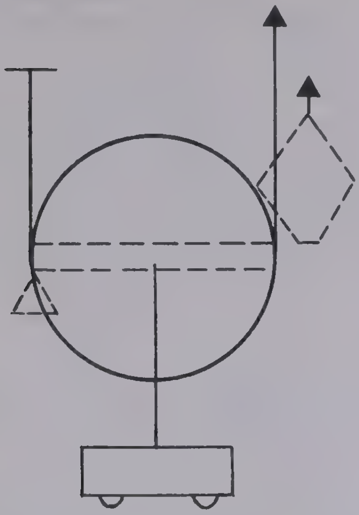
$$\text{M.A.} = \frac{a}{b}$$



2. The second-class lever makes work easier to do by extending the work done over a greater distance so that less force is necessary. The wheelbarrow, bottle opener, and nut cracker employ this principle in their operation.
3. The mechanical advantage may be increased by moving the cart closer to the fulcrum (decrease b). When the M.A. is increased, the force necessary to do the work is less, but the distance this force must move is proportionally greater.

Part D: Single-Moving Pulley
1. Again, the work done should be the same, but, due to friction in the pivot, using the pulley requires slightly more work.
2. The force needed to lift the cart using the pulley should be about one-half as great as the force necessary to simply lift the cart.

3. For a frictionless pulley, M.A. = 2, since the pulley may be considered a second-class lever, as below:



Part E: Block and Tackle

1. The M.A. of a block and tackle is given by the number of rope segments supporting the load; in this case 3.
2. None of these simple machines make it possible to lift the cart using less work. In fact, more work is often needed, due to friction within the machine.
3. The efficiency of most of these simple machines should be in the 85 – 95% range. In each case, it may be calculated as below:

$$\text{efficiency} = \frac{\text{work done by machine}}{\text{work done on machine}} \times 100\%$$

$$= \frac{\text{(force lifting cart) (height of books)}}{\text{(force exerted on machine) (distance force moves)}} \times 100\%$$

4. A machine's mechanical advantage tells you how much less force is needed when the machine is used to do work, ie. if M.A. = 4, only 1/4 as much force is needed.
5. A mechanical advantage of 1/2 would mean that 2 times as much force is needed using the machine. The advantage of such a machine is that the load is moved 2 times as far as the effort force. An example would be a fishing rod

8.8 Heat – Work

1. The width would increase also. A simple way to verify this would be to adjust a small crescent wrench to just slip over the rod when cool, and then try to do the same after the rod has been heated.
2. In this case its width would probably decrease, since its volume would remain constant.
3. If the plate were heated, the hole would increase in diameter, just as if the hole was merely a circle drawn on the surface of the plate. As the plate expanded, this circle would increase in diameter just as the hole does.
4. No! Each metal has its own characteristic amount of expansion when heated. If a bimetallic strip is heated, it would begin to bend into an arc, with the metal which expands the most on the outside of the curve. Thermostats in furnaces operate on this principle, using a bimetallic coil which expands or contracts as the temperature changes.

8.10 Work – Heat

1. In each case, mechanical agitation has caused the material's particles to move faster and hence feel hotter. Work has been done on the particles to cause them to move faster, and this work has produced heat.
2. High-speed power tools do produce tremendous amounts of heat as they operate. Special bearings and lubricants are used to minimize this heat, as well as cold air and water cooling systems, as on a dentist's drill.
3. As you rub your hands together, work is done on the particles comprising your hands and they begin to move faster, thus feeling warmer.
4. Using this idea, fires may be started by rubbing dry sticks together or striking one piece of flint rock against another, creating sparks.

8.12 Electricity – Work

1. As soon as the battery is connected to the coil, a force is exerted on the coil, causing it to move. Thus the battery is causing work to be done on the coil.
2. If the magnet's poles are reversed, the coil moves in the opposite direction.
3. Once again, reversing the battery terminals causes the coil to move in the opposite direction.
4. If more loops of wire are used on the coil, it seems to move faster and farther. This indicates that the force on it is increased. Doubling the force would double the amount of work done on the coil, only if the distance remained the same.

8.14 Light – Work

1. Light is causing work to be done on the radiometer because the radiometer begins to move when exposed to light, and stops when the light is removed.
2. No! The amount of work done on the radiometer seems to depend on the power of the light bulb, and its distance from the radiometer.
3. The radiometer rotates with the dark side trailing so that the dark side seems to be getting a greater push from the light.
4. Most of the air was removed from the glass bulb tc decrease the amount of air friction encountered by the rotating radiometer vanes.

8.17 Review

1. For work to be done on an object
   (i) a **force** must be exerted on the object
   (ii) the object must **move** in the direction of the force

(a) Yes, work is done on the dirt.
(b) No, no work is done on the curling stone – no force is acting on it, after it is thrown.
(c) Yes, work is done on the stone.
(d) No, the stone does **not** move in the direction of the force acting on it.

2. (a) $W = F \times d = (120\ N)\ (2.5\ m) = 300\ J$
   (b) $W = F \times d = (400\ N)\ (1.2\ m) = 480\ J$
   (c) $W = F \times d = (50\ N)\ (0.50\ m) = 25\ J$
   (d) $W = F \times d = (4.0\ N)\ (0.015\ m = 0.06\ J$
3. A lever with an efficiency of 75% is better since a greater percentage of the work done on the lever is actually transferred to the load. The effi-

ciency of a lever depends on how rigid the lever is and how little friction there is in the fulcrum.

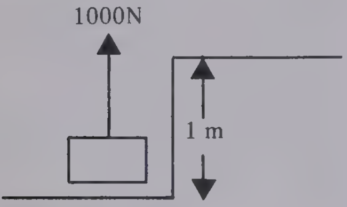
4. (a) M.A. $= \frac{\text{load}}{\text{effort}} = \frac{500\ \text{N}}{200\ \text{N}} = 2.5$

(b) M.A. $= \frac{600\ \text{N}}{240\ \text{N}} = 2.5$

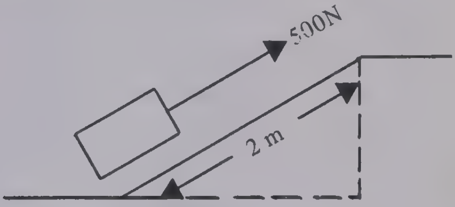
(c) M.A. $= \frac{1500\ \text{N}}{200\ \text{N}} = 7.5$

(d) M.A. $= \frac{400\ \text{N}}{160\ \text{N}} = 2.5$

5. Machines can make work "easier" to do by decreasing the force necessary to do the work and increasing the distance. For example, on a ramp:



lifting F=1000N
d=1 m
W=1000J



ramp F = 500N
d = 2 m
W=1000J

The crate may be moved from the floor to the shelf by lifting (using a force of 1000 N for 1 m) or sliding it up the ramp (using a force of 500 N for 2 m). The ramp makes the 1000 J of work easier to do.

6. Expansion joints are included in large structures to allow for thermal expansion and contraction caused by extremes of hot and cold weather. If these joints were not included, the structures would bend and buckle as they heated up and expanded.

7. When the air inside the balloon is heated, its particles move further apart and become less dense than the surrounding air. This creates a buoyant force upward on the balloon, which floats upward into the atmosphere until its density is the same as the surrounding air. In a sense, it floats in the air, just as solids float in liquids of equal or greater density in Chapter Four.

8. Static electricity is often produced when a comb is run through dry hair, girls in nylon stockings run around on wool rugs, and clothes rub together in a clothes dryer. In all cases, electricity is produced by two or more substances rubbing closely together.

9. A small lens held up in the sun can produce sufficient heat to ignite a small fire or a piece of paper. The lens must be held so that it focuses the sun's rays into the smallest spot of light possible on the paper. Be careful! The heat produced is enough to burn your skin.

10. Arabs and others living in hot climates wear light-coloured clothing because light shiny surfaces reflect heat and light whereas dark, dull surfaces absorb heat and light. On a hot summer day, the dark asphalt road would be much hotter than the lighter-coloured cement sidewalk due to heat absorbed rather than reflected.

CHAPTER NINE – ENERGY

9.3 Kinetic Energy

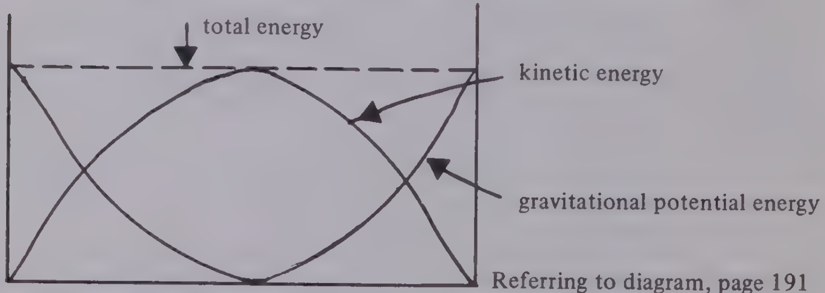
1. An object's kinetic energy is determined by its mass and speed. The more mass an object has, and the greater its speed, the more kinetic energy it has.
2. They hope to determine the bullets' kinetic energy, and therefore their speed.

9.5 Gravitational Potential Energy

1. The marble's mass and its vertical height when released both affect its gravitational potential energy.
2. Doubling the original height of the marble should double its energy.
3. Their gravitational potential energies are in the same ratio as their masses.
4. Just before entering the generating station the water possesses a large amount of gravitational potential energy and only a slight amount of kinetic energy. As the water falls, it begins to acquire kinetic energy as it loses gravitational potential energy.
5. Eventually, the generators which are turned by the kinetic energy of the water produce electrical energy.

9.7 Energy Conversion

1. The vertical height of position A should be equal to the vertical height of position B, since, if no energy is lost, the pendulum bob possesses the same amount of gravitational potential energy at both positions. This relationship appears to be verified by measurement in this investigation.
2. No more work is done on the pendulum after it has been set swinging, so its total energy should remain constant at all points in the swing.



Referring to diagram, page 191

3. As the pendulum continues to swing, the vertical height of the end position (A or C) decreases slowly. This occurs because the total energy of the pendulum is gradually decreasing.
4. The pendulum loses energy as it swings because of work done on it (against its motions) by collisions of the pendulum with air molecules in its path, and friction in the pivot.
5. A mass suspended on the end of a spring and a ball rolling back and forth in a semi-circular trough are other systems in which energy could be continuously converted from one form into another.
6. The height he achieves depends on his gravitational potential energy at the top of the jump. He gains this energy from the kinetic energy he acquires as he runs toward the jump. Since kinetic energy is determined by an

object's speed, the greatest height will be achieved when the vaulter attains the greatest speed prior to jumping.

9.9 Energy in Fuel

1. Usually this will be a very small increase, but if measured accurately will yield satisfactory results.
2. The heat gained by the water may be calculated, using:

   $H = m \times \Delta T \times 4.2$ where m is the mass of water in the beaker (0.1kg) and ΔT is its increase in temperature.
3. This is calculated from the previous question, as follows:

   $$\text{Heat in 1 ml of alcohol} = \frac{\text{Heat gained by water}}{\text{Volume of alcohol}}$$
4. The alcohol actually would contain more heat than the amount gained by the water. Some heat would be absorbed by the beaker, retort stand, and other apparatus, and some would be lost to the surrounding air by convection.
5. Burn them by soaking them in alcohol. Measure the amount of alcohol they absorb and subtract the heat content of this amount of alcohol from the heat released by the combustion of the alcohol and wood. The difference should represent the heat content of the wood.
6. A closed container is used so that the amount of heat lost by convection, conduction and radiation is minimized.
7. $$\Delta T = \frac{H}{m \times c} = \frac{420\ \text{kJ}}{(1\ \text{kg})\ (4.2\ \text{kJ/kg.°C})\ )} = 100°\text{C}$$
8. $$\Delta T = \frac{H}{m \times c} = \frac{5060\ \text{kJ}}{(60\ \text{kg})\ (4.2\ \text{kJ/(kg.°C)})\ )} = 20°\text{C}$$
9. To gain heat, your body "burns" fuel, in the form of carbohydrates stored within the cells of your body. To lose heat, you perspire, and the heat needed to cause this perspiration to evaporate is taken from your body, leaving it cooler.

9.13 Review

1. By the term energy, we mean the **ability to do work.**

   examples:
   (a) water at the top of Niagara Falls
   (b) a stone held back in a sling shot
   (c) a battery
   (d) a match
   (e) a car travelling along a straight level road
2. Both the Volkswagon and the Cadillac possess gravitational potential energy, but the Cadillac has more energy due to its greater mass.
3. As they begin to coast down a hill, they start to lose gravitational potential energy and gain kinetic energy so that at the bottom each possesses only kinetic energy.
4. Once again the Cadillac has more kinetic energy at the bottom of the hill because, due to its mass, it has more gravitational potential energy to start with.
5. Since the brakes do work to stop both cars, and therefore take away all of the object's kinetic energy, the Cadillac's brakes must do more work

because the Cadillac had more kinetic energy to begin with. Since both cars stopped in the same distance, the Cadillac's brakes must have exerted more force in doing the work.

6. (a) $H = m \times c \times \Delta T$

$$= (0.150\ \text{kg})\ (4.2\ \text{kJ/kg}\cdot{}^\circ\text{C})\ (10^\circ\text{C})$$
$$= 6.3\ \text{kJ}$$

(b) energy content of fuel is 6.3 kJ for 5 ml or $\frac{6300}{5} = 1260$ J/ml

(c) The kerosene contains chemical potential energy.

7. Nuclear generating stations are expensive to build, the fuel necessary is difficult to mine and purify, and the danger of nuclear radiation spills are expensive to safeguard against. Solar energy is inexpensive to use but methods of storing energy during extended non-sun periods are still being perfected. Solar energy conversion systems are large and expensive to construct and often rely on some other source of power to supplement their operation.

8. Public awareness campaigns and the spiralling increase in the cost of energy should prompt the public to adopt energy conservation measures, such as:

(a) increased use of insulation in homes
(b) controlling thermostats to lower home temperatures during the night
(c) doing clothes/dishwashing only with full loads
(d) showers instead of baths
(e) encouraging the use of smaller automobiles which get improved mileages per litre of gasoline.

CHAPTER TEN – THE FORCE BETWEEN PARTICLES

10.3 Forces between Soap Particles

1. The soap particles are pulling on each other to keep the bubble taut. When the film on one side is broken, the rest of the particles keep pulling and pull the thread over.
2. When your finger is removed from the end of the funnel, the soap bubble moves up the funnel to the smaller end. The soap particles are pulling each other, trying to shrink the surface area of the bubble.
3. There seems to be a fairly strong attractive force between soap particles.

10.6 Forces between Particles – Temperature

1. Cold water produces the largest drops.
2. The force between particles is largest in cold water.
3. The water molecules are closest together in cold water.
4. The force between water particles decreases as the distance between them increases.
5. In the last experiment, the force between water drops was sometimes attraction and sometimes repulsion. Here the force between water particles seems always attraction.

10.8 Forces between Particles – Distance

1. The distance might increase.
2. The force must increase.

3. The force seems to increase as the distance between molecules apparently increases.
4. Rubber forces seem to act differently from water particle forces. However, the distance between molecules in a rubber changes in a rather different way than our simple theory predicts. The long rubber molecules are coiled and tangled in a rubber band at rest. As the rubber band is stretched, its molecules straighten out and pull back.

10.10 Forces – Gas Molecules

1. As the distance between air molecules is decreased, the force increases.
2. The air molecules are not small enough to escape by the plunger of the syringe at any great rate.
3. The outside air pushing inwards keeps you from pulling the plunger out easily.

10.14 Electric and Magnetic Forces – Water

1. The stream of water is unaffected by magnets but deflected by electric charges. The molecules seem to be charged but not magnetized. The force between particles may be electric.
2. Water molecules probably have positive and negative charges on them.
3. If different molecules had different charges, then some would be attracted and others repelled by the charged strip. The stream would separate into two streams.
4. It acts more like a plastic strip, with a positive charge on one end and a negative charge on the other.
5. Both electric and magnetic forces increase as the distance between objects decreases.
6. Both electric and magnetic forces show attraction and repulsion – attraction for unlike poles or charges, repulsion for like poles or charges.
7. These forces may be strong enough, if the distance between the particles is small enough. The force of gravity is far too small to be the force.
8. If an apple has charges in it, there must be the same number or amount of each, so that the total charge is zero and the attractions and repulsions cancel each other out.
9. Electric force. The electric force affects more objects than does the magnetic.

10.17 Electrolysis of Water

1. negative
2. positive
3. Oxygen ions have negative charges.
4. Hydrogen gas has positive ions.
5. Twice as much hydrogen gas was collected as oxygen gas. If all gas molecules occupy the same space, there would be twice as many hydrogen as oxygen particles. If there are the same number of each molecule, then the molecules of hydrogen are twice as far apart as the molecules of oxygen.
6. Twice as many hydrogen molecules as oxygen molecules were produced.
7. Each water molecule contains twice as many hydrogen atoms as oxygen atoms. Perhaps there are two hydrogen atoms and one oxygen atom in each water molecule.

10.20 Review

1. An atom is one particle of a sample of an element.
2. A molecule is one particle of a sample of a compound.
3. A molecule is composed of several atoms.
4. Steel "particles" repel each other sometimes, and attract each other at other times.
5. Most forces decrease as the distance between the objects decreases. As steel is heated, the distance between atoms increases, and the force holding them together should decrease.
6. (a) electric force and magnetic force
   (b) gravity
   (c) It is doubtful that there is such a force.
7. The positive ends of the water molecules are attracted to the stream of water, and the negative ends repelled. The molecules are then pulled over to the charged rod. The force of attraction on the positive ends is larger than the force of repulsion on the more distant negative ends.
8. (a) Hydrogen particles must have a positive charge in the solution, while the oxygen particles are negative.
   (b) The gas collected is neutral. The particles must be neutralized when they touch the electrodes.

CHAPTER ELEVEN – REACTIONS BETWEEN PARTICLES

11.4 End-Product Amounts

1. The graph passes through (0,0) because zero magnesium produces zero hydrogen.
2. If each cm of magnesium produces the same amount of hydrogen, then the graph should be a straight line.
3. 10 ml/cm
4. yes

11.6 Reaction Rate – Temperature

1. A new product, a gas, is formed.
2. Heat increases the rate of reaction.
3. Heat speeds them up.
4. If the molecules are moving faster, they should collide more often, and increase the rate of reaction.
5. Surface area, pressure, concentration. At this point we give students a chance to predict other factors controlling rate of reaction.

11.7 Rate – Surface Area

1. Increasing the surface area increases the number of molecules exposed to the water, ready to be hit. More will be hit, increasing the rate of reaction.
2. If the beaker is stirred, clumps of powder will be broken up, exposing more molecules to the water and increasing the rate of reaction.

11.8 Reaction Rate – Concentration

1. If the concentration of hydrochloric acid is reduced, there will be fewer hydrochloric acid molecules in the solution to collide with magnesium atoms, and the rate of reaction will decrease.
2. If another strip of magnesium were dropped into the acid, it should take longer to react. The first strip has reduced the number of acid molecules available for reaction.

11.9 Rate – Pressure

1. When the cap is screwed on, the number of gas molecules inside the bottle increases. The pressure on the water is increased, and gas particles inside the water find it increasingly difficult to escape. The concentration of gas particles in the water builds up, and increasingly, they collide with magnesium particles instead of the acid particles. This slows down the rate of reaction.
2. On the moon there is no air pressure, and the gas could escape freely from the water. This should increase the rate of reaction considerably.

11.14 Review

1. (a) chem
   (b) phys - melting
   (c) phys - melting
   (d) chem
   (e) phys - freezing
   (f) phys - mostly dissolving
   (g) chem
   (h) chem
   (i) chem
   (j) phys - evaporation
2. (a) making instant milk
   (b) ice in a glass of pop
   (c) bacon fat stored in the refrigerator
   (d) liquid honey changes to a solid
   (e) making tea
   (f) using a furnace humidifier
3. (a) absorbed or released depending on the solute
   (b) absorbed
   (c) released
   (d) released
   (e) absorbed
   (f) absorbed
4. (a) endothermic
   (b) exothermic
   (c) endothermic
   (d) endothermic
5. increase the concentration of the reactants
   increase the temperature
   increase the surface area
   decrease the pressure (sometimes)
6. the opposite of 5

7. (a)

0_2	H_2	H_20	remainder	Kind
8	2	9	1	H_2
8	3	9	2	H_2
10	1	9	2	0_2
12	1	9	4	0_2
8	1	9	0	
16	2	18	0	
18	2	18	2	0_2
24	3	27	0	
32	7	36	3	H_2

(b) The total mass before the reaction and the total after must be the same.

(c) oxygen: hydrogen = 8:1

(d) 8:1

(e) (i) 8

(ii) 4

(iii) 8

(iv) 16

(v) 1

(f) (iv) is the closest

(g) 2.67×10^{-24}g

(h) 3.01×10^{-24}g

(i) 3.3×10^{22}

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